Use of information technology in mining ventilation

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Abstract: Mining ventilation is one of the most complex discipline, involving the use of mathematics, physics, fluid mechanics, aerodynamics and, last but not least, computer concepts. In countries with advanced mining, in recent years, there have been developed and used on a larger scale specialized software for modeling, solving and simulation of ventilation networks: 3D Canvent (CANMET Canada), Ventsim (Chasm Consulting, Australia), VnetPC PRO, etc. For carrying out simulations, and in particular for increasing the accessibility to required data obtained from simulation, for viewing, presenting and using the results, there can be used modern computer techniques, including "macro" subroutines that contain the whole chain of operations for the concerned area of the ventilation network structure and which can provide almost instantly feedback to the operator.

Key-Words: - mine ventilation, ventilation network, ventilation management, ventilation network modeling, CANVENT, simulation

1 Introduction

When we evaluate the broad issue of the occupational health and safety in underground coal mining, one very important aspect is to ensure proper microclimate conditions for carrying out specific activities and therefore adequate ventilation. In order to achieve this goal, it must be taken always into account, both in the initial planning phase, as well as in the operation and or restructuring, that the ventilation system must complement the mining method, and vice versa. A carefully engineered and chosen ventilation system can also give rise to better contingency, emergency and evacuation plans in times of emergencies [6].

The mine airflow distribution is completely defined by the following factors: (a) the physical parameters of the airways including shape, area, length and characteristics of the airway surface; (2) the layout of the mine openings; (3) the pressure sources (eg fans) in the system, their location and characteristics; and (4) the interconnections between the airways, mine openings and pressure sources [6], [4].

The main objective of the specialized software for modelling, solving and simulation of the mine ventilation network is to predict the airflow distribution and its modification, to estimate the pressure losses in the network, and to generate results that accurately approximates the ones determined by measuring campaigns, in the real system.

But the advantage of using the information technology doesn't stop here and goes beyond, providing a look into the future. Due the explosion in the IT domain, the fast and permanent evolution of the computer technology and of specialized applications, have been created the premises for a larger scale use of the computerized simulation techniques [1]. The benefits of using simulation for the mine ventilation domain could be summarized as follows [5]:

- Can help to make the right decision -Dynamic simulation techniques allow the user to test every aspect of a proposed change or different complex scenarios without committing any resources to its development;
- Exploring possibilities One of the greatest advantages of using simulation techniques is that once a valid simulation model has been developed, the engineering team can explore and evaluate new operating procedures, or methods without the expense

and disruption of experimenting within the real system;

- Diagnosis of existent or potential problems;
- Very useful tool, both in the planning phase and for preparing the restructuring of the network.
- Besides the programmed changes of the ventilation network structure, an underground mining operation may suffer significant changes during its operating life as new production areas open and old production stopes close; they may occur unpredictable events, or technically possible situations which could influence, sometimes substantially, the integrity and efficiency of the system. In order to minimize the effect of occurrence of such events, there may be performed, using the same specialized software applications, a series of "what-if" type simulations, to identify and visualize in real time the changes they may occur in the ventilation network [5], [2], [6].

In the literature, there are studies having as their object the optimization of the design, control and management processes for the mine ventilation networks, by dynamic, real-time generation of the network model, based on information automatically collected and transmitted from the underground, and the integration in the simulation exercises of components that characterize the climate conditions, that may influence the air and environment quality at the workplaces.

Through this paper work, the authors propose an innovative approach, the automation of the computer simulation carried out on a real, complex ventilation network. This is possible through the implementation of macros or subroutines which contains the whole chain of operations applied on the targeted areas within the ventilation network structure, subroutines that can be selected through an easy interface and that can provide an almost instantly feedback to the user.

2 Case study: ventilation network modeling for Uricani Mine, Romania

2.1 Short presentation of the Uricani Mine ventilation network

Uricani Mine is located in the western part of the Jiu Valley coal basin and is hoisting energetic hard coal from the underground.

The exploitation method currently in use at Uricani mining unit is the "Exploitation method

with longwalls and coal caving behind the front face". This method is applied based on the framework methods related to thick coal beds of medium and high inclinations [2].

The ventilation network of Uricani Mine consist in vertical mine workings which ensure the fresh air:

- Main Shaft with Skip (no.3) and auxiliary shaft no. 4, located in the central zone of the mining field;
- Shaft no. 7 Sterminos, located in the western extremity of the mining field;
- The slope (inclined plane) no. 15, located also in the central zone.

The return air is exhausted from the underground through the depression made by two ventilation stations, situated as follows:

- Ventilation shaft East, in the eastern part of the mining field;
- Ventilation shaft West.

Uricani Mine is structured in depth on four horizons: 575, 500, 400 and 300. The mine working at the horizons levels are interconnected through vertical mine workings or by inclined mine workings (slopes, risings, etc.).

Currently, the mine has in operation three blocks: block no. III, block no. IV and block no. V.

The total length of the mining works exceeds 32 km.

2.2 Modeling the Uricani Mine ventilation network, using 3D-CANVENT® Software

3D-CANVENT is a numerical modeling system for underground mine ventilation analysis. The fullyfeatured Windows application can simulate ventilation systems with various operating parameters from ventilation surveys and determined from known airways. New ventilation systems can also be simulated based on conceptual mine layouts and ventilation parameters estimated for airways in the network [8].

The software is able to analyze incompressible flow, which is suitable for most of ventilation networks, and compressible flow with supplied air density and natural ventilation data for deep mines and other special purposes [8].

Achieving the model of the ventilation network related to Uricani mining unit has required the following steps: [2], [8]:

- Obtaining the spatial map of the mine and the basic topographic drawings, at each horizon level;
- marking the nodes (junctions between the galleries) on the spatial map of the mine;

- collecting geodesic coordinates for the nodes of the network;
- carrying out pressure and airflow measurements for each branch of the network;
- calculating specific parameters and their transposition in an accessible format which is compatible with 3D-CANVENT;
- data input into the CANVENT database;
- ventilation network modelling (fig. 1);
- Ventilation network optimization or balancing.



Fig. 1. 3D Model of the Uricani Mine ventilation network; views in different planes



Fig. 2. 3D Spatial map of the Uricani Mine ventilation network, in the current state, after modeling

All the above mentioned steps have been applied for the concrete conditions of the entire ventilation network related to Uricani Mine. After modeling, there have resulted a number of 349 junctions and 548 branches (fig. 2).

3 Case study: Simulation of a complex, potential modification on the modeled ventilation network

3.1 Description of the simulated scenario

Starting from the modeled and solved ventilation network related to Uricani Mine, a complex simulation was performed, consisting in closing the west wing of the mentioned mining field. This technically possible scenario implies the exclusion of the following mining works from the ventilation network (fig. 3):

- a) Main West Gallery, horizon 500;
- b) The circuit of Ventilation Shaft West, horizon 500;
- c) Ventilation Shaft West channel, horizon 400;
- d) Main transversal gallery, horizon 400;
- e) Demag West mainline gallery, horizon 300;
- f) Inclined plane 300-400, block 0;
- g) Main gallery, horizon 400;
- h) Ventilation gallery, horizon 400;
- i) Circuit of Ventilation Shaft no. 7 Sterminos, horizon 400;
- j) Ventilation Shaft no. 7 Sterminos;
- k) Ventilation Shaft West;
- 1) Channel of Ventilation Shaft West.



Fig. 3. Details of the western zone of the network, which closing makes object for the simulation

In this regard, after the careful analysis of the model, results the need to achieve the following works:

- a) Stopping the Main Ventilation Station, Shaft West;
- b) placing an insulation construction on the main West Gallery, horizon 500; placing an insulation construction on de Demag West mainline gallery, horizon 300;
- c) closing of the Ventilation Shaft No. 7 Sterminos;

d) closing of the Ventilation Shaft West, respectively of the West Shaft ventilation channel;

Doing these works, there have been placed 5 insulation constructions in the ventilation network, as follows:

- one stopping on the Demag West mainline gallery, horizon 300 (after the block III North);
- 2) one stopping on the main West gallery, horizon 500;

- one stopping in the ventilation channel of the Shaft West;
- 4) one closing plate placed on the top of the ventilation Shaft West
- 5) one closing plate placed on the top of the ventilation Shaft No. 7 Sterminos.

3.2 Interpretation of the results obtained after the simulation

Following the completion of the simulation a new model resulted for the ventilation network. This model reflects a new natural distribution of the airflows al each branch level, under the action of the depression developed by the East Main Ventilation Station.

At the same time, there can be observed inversions of the direction of the airflows:

at the block III North level (branches 289-290, 290-291, 291-275);

- in the central area of the ventilation network (branches 10-26, 25-26, 215-216, horizon 500);
- in the area of circuit Shaft with Skip Auxiliary Shaft No. 4 (branches 5-53, 61-75);
- at the horizon 500 level, west wing (branches 208-209, 209-210, 210-211, 211-214, 214-215);
- at the level of Delta Demag gallery, horizon 400 (branch 304-307);
- in the area of block IV South, horizon 300-400 (branches 191-132, 192-191, 132-131, 194-195, 195-196).

We also can observe modification regarding the distribution of the airflows, respectively changes of the aerodynamic parameters specifics to the Main Ventilation Station, as follows:

- A drastic decrease of the airflow circulated in the Shaft with Skip, from 35.16 m³/s to 18.61 m³/s;
- A drastic decrease of the airflow circulated at the level of the Auxiliary Shaft No. 4, from 43.19 m³/s to 25.89 m³/s.

At the stopes level the following may be observed:

- an insignificant decrease of the airflow at the level of stope Panel 7, bed no. 3, block III North, from 4.56 to 4.32 m³/s;
- an insignificant decrease of the airflow at the level of coal face Panel 6N, bed no. 3, block III North, from 4 m³/s to 3.78 m³/s;
- an insignificant increase of the airflow circulated in the Panel 5, bed no. 3, block IV South, from 6.54 m³/s to 6.64 m³/s;
- A drastic decrease of the airflow at the level of the Panel 11, bed no. 5, Block IV North, from 12.78 m³/s to 4.71 m³/s.

Regarding the East Main Ventilation Station, we can observe a minor increase of the airflow, from $44.51 \text{m}^3/\text{s}$ to $46.67 \text{m}^3/\text{s}$. The resistance of the network related to the East Main Ventilation Station has significantly decreased, from $0.982 \text{ Ns}^2/\text{m}^8$ to $0,773 \text{ Ns}^2/\text{m}^8$.

The depression developed by the active fan of the East Main Ventilation Station has decreased moderately from 1766.5 Pa to 1684.5 Pa.



Fig. 4. The model of the Uricani Mine Ventilation Network, after the complex scenario simulation



Fig. 5. Details of the western zone of the network, after the simulation

3.3 Use of the AutoHotKey open-source development environment for the automation of the above described simulation

In order to increase efficiency at the user level, to increase visibility while reducing the level of complexity requested for understanding of the phenomena that occur into the ventilation network, modeled and solved using specialized application (e.g. 3D-CANVENT), there had been searched solution to automate the execution of the needed steps involved in simulation processes, of the above described nature.

It was intended that these solutions to act as an interface between the user and the 3D - CANVENT software.

AutoHotKey may be considered as one of these solutions. It is an open-source development environment that provides almost limitless possibilities of automation and optimization of the user activity. Using this scripting language, we can create small subroutines of "macro" type, which contains the chain of all operations required to be done for each step of the simulation process. It provides the ability to create custom graphic user interfaces (GUI) with windows, menus, copy data from different applications, process and then reinsert them in the desired location.

Each script is a text file created independently of the used editor, and contains commands to be executed by the program (AutoHotKey). A script may contain hotkeys (shortcuts or combination of keys with different functions: open, save or print a file, etc.) or emulate mouse clicks, navigation through menus, etc. The script is parsed sequentially, from top to end, but it is possible to insert instructions to jump to a specified line of code, in order to execute particular subroutines.

The subroutines created with AutoHotKey language an assign / retrieve values to / from variables, can run loops and even manipulate windows and folders, proving a very good integration with the native Windows libraries. There can be written even more advanced programs, user interfaces of Windows GUI type, customized forms for data input and process, modifying the system registers or using Windows API functions, by calling the libraries from .dll files.

The created scripts can be then compiled in executable files that can be run on machines that not have AutoHotKey installed, may be assigned to a combination of keys, so that they can be activated by the user whenever desired.

The engine behind AutoHotkey is impressive. The software is miniscule, lightning fast, and stable. Then again, since it has no user interface of any kind, AutoHotKey may be defined been more of a development environment and coding language than an application.

Besides the benefits of zero cost, given by the status of open-source application, AutoHotKey has other features that recommend it: easy of programming, flexibility, access to documentation and discussions forum, etc. The online community forum for AutoHotkey has around 27,300 registered users and around 482,000 posts as of January 2012 [9].

The using of scripts created by this software instrument (fig. 6) to interact with the 3D-CANVENT application for the simulation of the technical possible events that may occur into the mine ventilation network, significantly reduce the time preparing the simulation.

The command lines composing the script interact with the 3D-CANVENT interface, modifying data associated to ventilation network model: junction coordinates, airways lengths, airway symbol and ventilation constructions, information regarding resistances, the measured flow rates, etc.



Fig. 6. The script created with AutoHotKey for 3D-CANVENT task automation



Fig. 7. Comparative image of the ventilation network model, before and after the simulation

Once the simulation was run, all the involved steps, as were described in the previous section, are stored in the source code of the script; each subsequent running of the script gives the user an almost instant feedback, providing all technical data related to the ventilation network: airflow distribution at each branch level, pressure loss distribution, the areas with airflow reversion, aerodynamic parameters specific to the main ventilation stations, and so on, data which provide optimal decision making, thus ensuring a higher degree level of occupational health and safety.

After accessing the desired subroutine, the user has unlimited and concurrently access to both modeled and solved ventilation network as well as to modeled, solved and simulated network (fig. 7).

Using this approach in programming the subroutines to control the simulations of the events for each knows area with high potential risk from the ventilation network spatial scheme, and the selection of different scenarios through a simple graphical user interface (fig. 8), any operator, even having a lower level of knowledge in using 3D-CANVENT software, can briefly analyze and interpret the changes occurred from different simulations on the ventilation network model.

Additionally, in order to obtain a clearer picture of the steps taken, namely the changes made to the model of the original ventilation network, the script can be programed to generate a text file (log) containing simulation history (fig. 9).

H Ventilation Network Simulation	
Simulation Automation	
Options	
Initial State Launch Simulation	
Exit	

Fig. 8. Simple graphic user interface

Using the results of these simulations we can build after a knowledge base, specific to each mining unit, which can help improving the occupational health and safety level through forecasting and establishing a priori a set of operations required for insulation and limitation of the post incident effects.



Fig. 9. Text files created by the script, which logs the history of changes automatically operated

4 Conclusions

Modern techniques of computerized simulation represents today a very useful tool for assisting the mine ventilation, in order to ensure an optimal microclimate at workplace, in accordance with the legislative requirements regarding the occupational health and safety.

Updating of the ventilation network is a dynamic process continuously correlated with the development of underground mining.

The advantage of using 3D-CANVENT specialized application lies in its ability to model, solve and simulate an almost unlimited number of potential situations, generating results comparable with a good accuracy with those obtained by underground measurements.

By automating the simulation process there can be carried out macro subroutines, containing the entire series of operations on the areas concerned from the ventilation network structure, for each mining unit of interest, subroutines that can be selected via an easy interface and provide fast user feedback.

The contribution of this paper work is to present the yet unexploited potential offered by the application of knowledge from different but complementary research areas, such as mining engineering, ventilation and information technology.

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