ESTABLISHING THE STRUCTURE OF VENTILATION NETWORKS AFFECTED BY UNDERGROUND EXPLOSIONS

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Abstract
The explosion-type phenomenon is an extremely complex physico-chemical process leading to the physical change of objects and objectives met on the propagation pathway as well as to the chemical change of underground atmosphere in the area of influence. During the development of the explosion-type phenomenon, due to the energy of the dynamic wave, there are generated significant mechanical effects at the level of the affected mining works as well as at the level of ventilation constructions. In addition, due to intense burning reactions at high temperatures, there occur major effects related to the composition and concentration of the underground atmosphere in the area of influence. Changes, respectively perturbations occurring after the event at the level of underground works or coal faces, endanger the entire working staff and may lead to the occurrence of similar phenomena. An explosion has direct effect upon the ventilation network due to the change of operational parameters of main ventilation fans. This leads to a different post-event natural repartition of air flows at branch level. Also, the underground atmosphere in the coal face changes, fact which leads to the increase of the potential risk of a new underground explosion occurrence, respectively to major difficulties regarding the withdrawal of work staff affected and of specialized intervention staff. Prior establishment of post-event work environment is performed through simulations on a ventilation network using the Australian VENTSIM VISUAL ADVANCED software.
Keywords: *ventilation, explosion, modelling, simulation*

1. Introduction

In normal energetic coal exploitation in underground occur different types of gases in variable concentrations in the work environment. The most representative and the most hazardous for work staff are methane, carbon monoxide and carbon dioxide.

Larger quantities of gas are usually releases in active coalfaces during technological processes and during coal spontaneous combustion processes.

1.1. Establishing gas concentrations before the event

Largest gas concentrations are usually released in active coal faces, during technological processes, as well as during coal spontaneous combustion phenomena. In order to establish gas concentrations at the level of a coal face, there are performed specific measurements during a one week period. Maximum concentration is recorded during actual exploitation works, and minimum values are registered during the resting period at the end of the week.

After the occurrence of an explosion type phenomenon, the level of air concentrations is close or identically to the one registered in the resting period of the week.

1.2. Establishing gas concentrations after the event

Q_1 circulated air flow at the level of the coalface is considered, then:

$$Q_1 = \frac{q_a \cdot 100}{c_1} \qquad (m^3/min)$$

where:
q_a–absolute gas flow (methane or carbon dioxide) specific to the coalface (m^3/min);
c_1 – average concentration of methane or carbon dioxide during rest days from the end of the week (%);

After the event, the circulated air flow at the level of the coalface is Q2, obtained by simulation using VENTSIM VISUAL ADVANCED software (m^3/min).

$$Q2 = \frac{q_a \cdot 100}{c_x} \qquad (m^3/min)$$

where:
q_a-absolute gas flow (methane or carbon dioxide) [8 ;9 ;10 ;16 ;17] specific to the coalface (m3/min);
c_x – average concentration of methane or carbon dioxide after the event (%);

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There can be written the following relation:

$$c_x = c_1 \cdot \frac{Q_1}{Q_2} \quad (\%)$$

2. Establishing the changes in the work environment after the occurrence of an underground explosion

Relevant for establishing the work environment after the occurrence of an explosion are information regarding the change of gas concentrations (CO_2, CH_4, CO) and of air flow [4;6;11;13;18;21].

In this regard, for establishing environmental conditions after the occurrence of an explosion there is required to perform several steps:

- Simulation of explosive and or toxic gas dispersion, in normal exploitation conditions;
- Establishing the structure of the ventilation network after the occurrence of an explosion;
- Simulation of explosive or toxic gas dispersion after the occurrence of an explosion.

2.1. Establishing the structure of the ventilation network after the occurrence of an explosion

In order to establish the structure of the ventilation network after the occurrence of an explosion the following steps shall be performed:

- Establishing the influence of the explosion type phenomenon upon the ventilation network;
- Solving the ventilation network by taking into account the changes generated by the explosion

2.2. Establishing the structure of the ventilation network after the occurrence of an average intensity explosion

In order to establish the structure of the ventilation network after the occurrence of an explosion [1; 2; 3;12;14;19], the following steps shall be performed:

- Establishing the influence of an explosion type phenomenon of average intensity upon the ventilation network;
- Solving the ventilation network by taking into account the changes generated by the explosion

2.2.1. Establishing the influence of an explosion type phenomenon of average intensity upon the ventilation network

The explosion of a gaseous mixture is an extremely complex physic-chemical process depending on various factors:

- explosive mixture volume;
- type of explosive gas;
- structure of the accumulation area;
- gaseous mixture flow regime;
- existence or non-existence of support over the propagation path;
- type of ignition source etc.

Any change of one of the factors of influence leads to a high variation of explosivity parameters.

In order to identify the effects of an average intensity explosion, there shall be firstly established:

- Ventilation network on which the simulation is performed is the one of Vulcan mine;
- The chosen area for simulating the explosion is the coal face with undermined coal bed no. 1/3/VII;
- Length of the coal face: 54 m;
- Volume of the explosive mixture:375 m^3.
- Length of the face over which the methane accumulation takes place: 40 m;
- Section of the face: 9.375 m^2;
- Air-methane concentration 5 % vol.;
- Ignition source– spontaneous combustion phenomenon degenerated into an endogenous fire;
- Approximate explosion pressure: 6 bar.

A. Rate of pressure rise

The rate of pressure rise dP/dt_{max} is given by [7] the cubical law:

$$\frac{dP}{dt}\max = K_g V^{-1/3} \qquad \text{(bar/s)}$$

in which:

V – volume of the enclosure m^3;

K_g – gas characteristic constant, for turbulent mixture, with a value of 460;

$$\frac{dP}{dt}\max = 63{,}79 \text{ bar/s}$$

B. Determination of the explosion pressure loss gradient in relation with the propagation distance

The explosion type phenomenon determines in open space the occurrence of dynamic shockwave [20] propagation spherically in the environment, Figure 1.

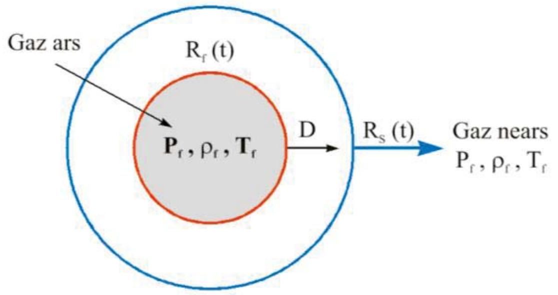

Fig.1 *Spherical propagation of the explosion in open-environment by I Sochet*

The propagation of the pressure wave in underground conditions is achieved on the alignment of mining works generating the tunnel effect. The spherical component of the pressure wave which is not directed on the alignment of mining works is adsorbed or reflected by the mining support, respectively by the rock massif.

The pressure variation in time [2] is presented in Figure 2.

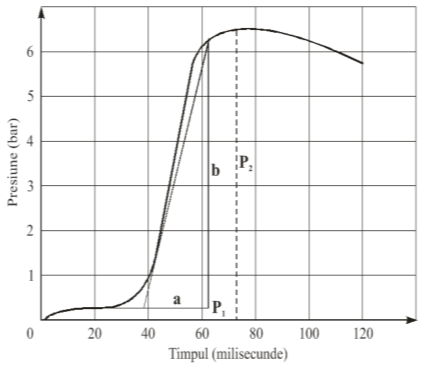

Fig.2 *Variation of pressure in time by C Cîrloganu*

The explosion pressure variation on relation with the propagation distance is presented in Figure 3 [15].

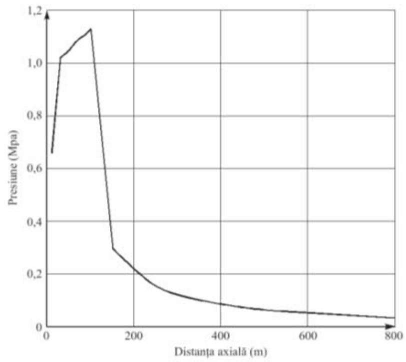

Fig.3 *Explosion pressure variation on the propagation path by P. Lei, T. Jialei, Y. Wei, X. Yabo*

The explosion also generates an increase in temperature which in case of methane may range from 2000 K up to 2500-2800 K. Variation of explosion temperature in relation with distance form epicentre is presented in figure 4 [15].

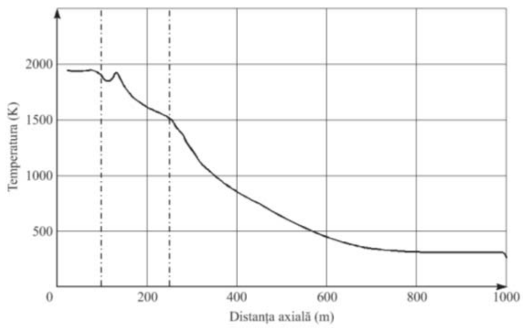

Fig. 4 *Explosion pressure variation in relation with distance by P. Lei, T. Jialei, Y. Wei, X. Yabo*

For establishing the average gradient of pressure loss dP/dx there were taken into account two experiments performed in underground conditions. The first experiment was conducted in Romania by Bana F. in the 100 m in length experimental tunnel from INSEMEX Petrosani [1; 2; 14]. Within this experiment was ignited a 50 m^3 explosive mixture with 5% vol. methane concentration (Fig. 5)

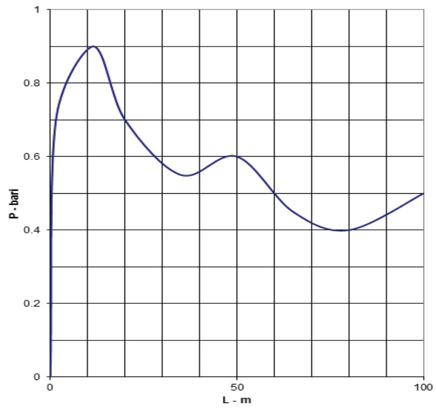

Fig. 5 *Explosion pressure variation in relation with distance*

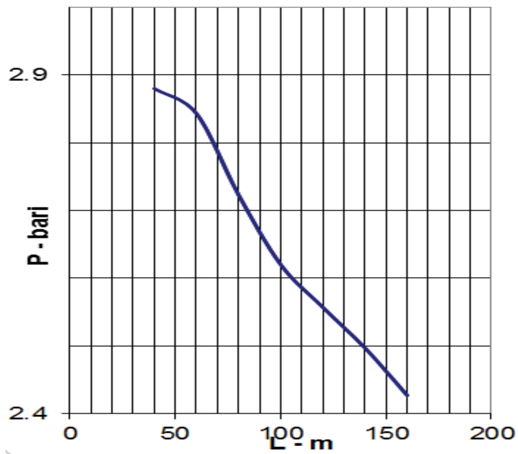

Fig. 6 *Explosion pressure variation in relation with distance*

From Fig. 5 the maximum average pressure loss gradient is dP/dx = 0.4 bar / 100 m.

From Fig. 6 the maximum average pressure loss gradient is dP/dx = 0.3775 bar / 100 m.

Taking into account experiments have been performed in tunnels with relatively reduced lengths of 100 m, respectively 896 m compared to the length of the mining works from within an underground mine which may add up to tens of km, with a high complexity degree from the structural point of view, there is considered the maximum pressure loss gradient of dP/dx = 0.35 bar / 100 m to be covering.

Taking into account the explosion pressure of 6 bar, respectively the values of 0.07 bar and 0.15 bar for which ventilation doors, respectively insulation constructions structurally collapse, it results that the dynamic wave generated by the explosion destroys the following ventilation doors belonging to the uniquely identified branches: 52; 63; 70; 103; 137; 147; 170; 171; 187; 197; 200; 202; 216; 258; 278; 286, respectively the insulation constructions belonging to the uniquely identified branches: 226; 230. There were also modified the specific parameters of regulation and insulation doors from branches with unique number: 276; 285; 309 and 310.

2.2.2. Ventilation network solving in relation with changes generated by the explosion

Figure 7 presents the spatial ventilation network of Vulcan mining unit in 3D solid format, modified with regard to the structural changes generated by the explosion [23].

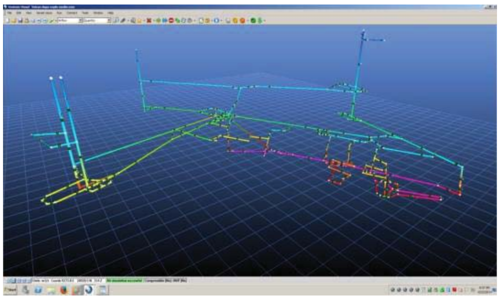

Fig. 7 *Vulcan mine ventilation network after the occurrence of the explosion*

3. Simulation of explosive or toxic gas dispersion after the occurrence of an explosion

For achieving the simulation in order to establish the dispersion of explosive and or toxic gases after the occurrence of an explosion type phenomenon, the following steps shall be performed:

- Simulation of CH_4 dispersion at ventilation network level;
- Simulation of CO_2 dispersion at ventilation network level;
- Simulation of CO dispersion at ventilation network level;

Change in ventilation network structure brings along the change of airflows at branch level and as a consequence occur major changes of gas concentrations in areas of influence

3.1. Simulation of CH_4 dispersion at ventilation network level

Figure 8 provides the simulation of methane dispersion at ventilation network level, representing the area of the active coal face no. 2/3/VI from Vulcan mine unit.

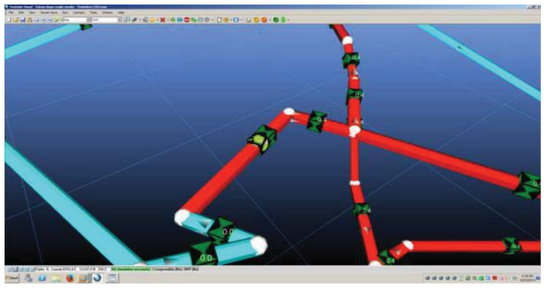

Fig. 8 *CH_4 dispersion in the undermined coal bed no. 2, bed no. 3, block VI*

Following the simulation of methane dispersion at the level of the ventilation network, the following results have been obtained:

- CH_4 concentration at the level of the face with undermined coal bed no. 2, bed no. 3 bl. VI with unique no. 55, has been of 0.4 % vol.;
- CH_4 concentration at the level of the face with undermined coal bed no. 1, bed no. 3 bl. VII with unique no. 191, has been of 1.5 % vol.;
- CH_4 concentration at the level of the face with undermined coal bed no. 1, bed no. 3 bl. VIII with unique no. 214, has been of 2.9 % vol.;
- CH_4 concentration at the level of the faces no. 1 – no. 4, bed no. 3 bl. VIII with unique no. 223, has been of 0.5 % vol.;
- At the level of the main ventilation station, branch no. 304, CH_4 concentration has been 0.1 % vol.

3.2. Simulation of CO_2 dispersion at ventilation network level

Figure 9 provides the simulation of carbon dioxide dispersion at ventilation network level, representing the area of the coal face 1-4, bed 3, block VIII.

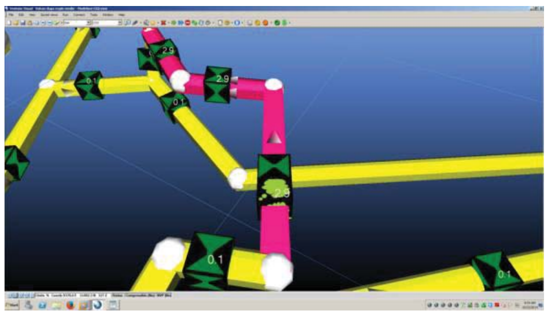

Fig. 9. *CO_2 dispersion in the undermined coal bed no. 1-4, bed no. 3, block VIII*

Following the simulation of carbon dioxide dispersion at ventilation network level, the following results have been obtained:

- CO_2 concentration at the level of the face with undermined coal bed no. 2, bed no. 3 bl. VI with unique no. 55, has been of 0.2 % vol.;

- CO_2 concentration at the level of the face with undermined coal bed no. 1, bed no. 3 bl. VII with unique no. 191, has been of 3.1 % vol.;
- CO_2 concentration at the level of the face with undermined coal bed no. 1, bed no. 3 bl. VIII with unique no. 214, has been of 1.9 % vol.;
- CO_2 concentration at the level of the faces no. 1 – no. 4, bed no. 3 bl. VIII with unique no. 223, has been of 2.9 % vol.;
- On the ventilation shaft, branch with unique no. 274, CO_2 concentration has been 0.2 % vol.
- At the level of the main ventilation station, branch no. 304, CO_2 concentration has been of 0.1 % vol.

3.3. Simulation of CO dispersion at ventilation network level

Figure 10 presents the carbon oxide dispersion at Vulcan mine's ventilation network level, representing the area of the active coal face no. 1/3/VIII.

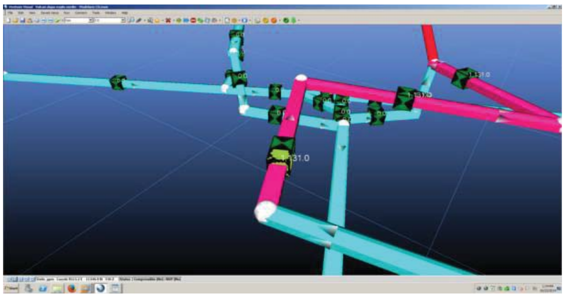

Fig. 10 *CO dispersion in the undermined coal bed no. 1, bed no. 3, block VII*

Following the simulation of carbon oxide dispersion at ventilation network level, the following results have been obtained:

- CO concentration at the level of the face with undermined coal bed no. 1, bed no. 3 bl. VII with unique no. 191, has been of 1131.0 ppm;
- On the ventilation shaft, branch with unique no. 274, CO concentration has been 40.8 ppm;
- At the level of the main ventilation station, branch no. 304, CO concentration has been of 12 ppm.

4. Conclusions

Methane release in areas of front faces is a complex phenomenon, which depends as value and intensity on a series of natural-geological and technological factors.

For establishing the methane, carbon dioxide and carbon monoxide concentration after the event, there has been used the absolute gas flow method.

Identifying environmental conditions after the occurrence of an explosion consists of the following phases:

- Simulation of explosive or toxic gases dispersion, in normal exploitation conditions;
- Establishing the structure of the ventilation network after the occurrence of an explosion;
- Simulation of explosive or toxic gas dispersion after the occurrence of an explosion;

Establishing explosive or toxic gas dispersion before and after the occurrence of an explosion, involves the following simulations at the level of Vulcan mine unit:

- CH_4 dispersion simulation;
- CO_2 dispersion simulation;
- CO dispersion simulation.

Results on the dispersion of methane, carbon dioxide and carbon oxide after the occurrence of an average intensity explosion are the following:

- CH_4 presence at the level of coal-faces in concentrations of 0.4-4.3 % vol.;
- CO_2 at the level of coal-faces in concentrations of 0.2-3.1 % vol.;
- CO presence at the level of a single coal face, in concentration of 1131. 0 ppm.

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