MINISTRY OF EDUCATION
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DOCTORAL FIELD OF MINE, OIL AND GAS

# DOCTORAL THESIS
## - SUMMARY -

# ANALYSIS OF VENTILATION NETWORKS AFFECTED BY THE PHENOMENON OF EXPLOSION

**PhD supervisor,**
**PhD. Eng. Prof. COZMA EUGEN**

**PhD Student,**
**Eng. GHERGHE ION**

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# CONTENTS

The research activity carried out in order to elaborate the thesis and the fulfillment of the specific objectives, is based on two proposed subject matter vectors, namely through the use of the specialized IT equipment used for modeling, simulation and determination of the optimal distribution of the airflows of the mining objectives in operation ,respectively the optimization and simulation on the complex ventilation networks of virtual explosion-like phenomena that may occur in different areas of the mine workings network.

The thesis contains 163 pages, it is structured in 11 chapters, plus the bibliography and annexes.

The first chapter, titled *"General ventilation concepts"*, makes a review of the parameters of the mining climate, the comfort of work and its relation to the climatic factors, respectively notions about natural circulation with the presentation of the methods of calculating the natural draught and the carrying out the general ventilation.

By "natural draught" of an underground mining operation, is to be understood the air flow in the mining works network under the influence of natural factors. Formation of natural draught is possible in the presence of two or more vertical or inclined shafts and different air densities in these works.

Concerning general ventilation, are presented the basic laws governing mining and especially the types of fans used in the mining industry

Ventilation in underground mines is required to dilute and remove hazardous substances, control the heat, and provide oxygen for humans.

In Chapter II, titled "*Analysis of ventilation networks*", the techniques used to solve the ventilation networks and the impact of digital computers in the field of ventilation planning are dealt with.

It starts from the analysis of the basic laws applied to the ventilation networks, namely Kirchhoff's laws, the quantum law of air flow, which is the basic relation for the current air-flow planning, respectively the methods for solving the ventilation networks.

The first method involves combining all branching in series and parallel in the form of equivalent resistances. The second method is the analytical solution of the equations obtained by direct application of Kirchoff's laws.

The third method is to use physical or analogical models of the mine's ventilation system, and ultimately the latest method of successive approximations that has gained ground with the evolution of electronic computers.

The method selected for a particular problem depends on the complexity of the network to be analyzed.

Chapter III, titled "*Use of IT equipment and specialized software to solve ventilation networks*", analyzes modern methods and tools that can be used to model, solve, optimize and simulate complex ventilation networks.

In this sense, the best performing specialized mining ventilation programs are described and analyzed, such as: VentSim Visual Advanced, VentGraph, 3D-Canvent, MVS - VentPC, MineFire, DuctSIM, Vuma-3D and Ven pri.

Ventilation has been a major concern in underground mines for hundreds of years, but until the introduction of computerized ventilation analysis over the last 40 years, ventilation planning and modeling has been largely difficult, relying on experience, assumptions and extensive calculations.

Even when computer ventilation software has allowed simulations of large ventilation networks, the work process and interpretation of the results has remained accessible only to experts in the field. The specialized programs are designed to simulate ventilation networks accessible to any mine engineer or ventilator specialist.

In Chapter IV, entitled *"Analysis of the air system of Lupeni mine after updating the ventilation* network", the mine's ventilation network is professionally treated.

Thus, the structure of the Lupeni mine ventilation network was analyzed, describing the main and secondary ventilation circuits, respectively the use of VentSim Visual Advanced database for updating and solving the Lupeni mine ventilation network used in the intermediate phase, geodetic data specific to the structural changes of the ventilation network, namely flow-metric and depresiometric measurements performed in situ.

For the updating of the Lupeni mine ventilation network modeled and solved in the two stages (initial and intermediate), in the first phase the main air vent 1Est ventilation station placed on the branch 290-291, was neutralised.

A number of 77 circuits and ramifications with unique registration numbers were removed from the initial database, adding a number of 27 circuits and branches with unique registration numbers

A number of 343 knots and 449 branches were introduced to solve the Lupeni mine ventilation network.

Chapter V, titled *"Explosion Risk",* presents theoretical notions about the nature of the risk, the severity classes, the relationship between risk and security with the notion of acceptable risk, the risk factors for injury and professional illness grouped by the criterion of the generating element from the work system.

Also, the explosion phenomenon was treated in the explosion risk, with its production mechanism, the influence factors and the explosion parameters.

The main measure to prevent explosions is to provide adequate ventilation to ensure the dilution of explosive gases.

Ventilating the mine workings is aimed at achieving three main objectives:

- ensuring the oxygen concentration necessary for underground personnel;
- dilution of explosive and / or toxic gases that may occur in the mine workings network;
- evacuation of the humidity and heat resulting from the human activity or the geothermal gradient that flows into the mine workings network.

Chapter VI entitled *"Explosions in underground coal mines"* presents explosive environments with build-up areas and sources of ignition, underground explosions and the effects of underground explosions.

For an explosion phenomenon to occur, it is necessary to overlap in time and space the three factors - fuel, oxygen required to participate in the explosion in the air, respectively the efficient source that presents energy sufficiently high to initiate the mixture.

There are also presented possible areas of methane and / or coal dust accumulation and potential sources that can be encountered in underground explosion.

At the level of the underground mine workings, the following types of explosions may occur:

- Methane explosions;
- bursts of coal dust;
- Explosions of methane gas and coal dust.

Under the effects of underground explosions are the phenomena of explosion with the effects they produce, namely, dynamic, thermal and chemical effects.

In Chapter VII, entitled *"Changes in the ventilation network due to the occurrence of an explosion phenomenon"*, there are presented notions regarding the ventilation networks and the changes arrisen in the ventilation networks due to the occurrence of an explosion phenomenon

A ventilation network consists of nodes and branches. Also, the ventilation network is made up of circuits and sub-circuits, which generate simple and complex canonical schemes. At the branch level, they are connected in series parallel or diagonal.

Ventilation constructions are used for routing the airflow of each ramification, respectively for closing the mine workings.

Thus, in the event of an underground explosion, major airborne disruptions occur in the ventilation network due to:

- Partial destruction of the control and isolation doors;
- total destruction of the control and isolation doors;
- destruction of insulation constructions;

- surges occurring on mining works adjacent to the epicentre of the explosion;

Due to these situations, the following effects may occur:

- preserving the airflow with:
- reduction of air flow on certain branches;
- increasing the air flow on certain branches;
- reversing the airflow on certain branches;
- intensification of existing spontaneous combustion phenomena;
- the occurrence of new spontaneous combustion phenomena;
- increased carbon dioxide concentrations (up to 2-3% vol.);
- decrease in oxygen content (up to 3-7% vol.).

In Chapter VIII, titled *"The Effect of an Explosion on the main ventilation station"*, an analysis of the effect of an explosion on the main ventilation station and the analysis of the transient phenomena was carried out.

Depending on the intensity, the phenomenon of explosion that occurs underground can be of small, medium and high intensity. Depending on the intensity, an underground explosion can develop a pressure of up to 11 atmospheres.

The main ventilation station at gassy mines is always located downstream of the site of an underground explosion on the vicious evacuated airway path, being the last portion of the ventilation network before the dynamic wave enters the atmosphere.

The most common situation regarding the effect of an explosion on the main ventilation station is the scenario that generates destructive effects while maintaining the main fan operating capability when the explosive intensity is sufficiently high that the forces generated by the dynamic wavelength are higher than the breaking strength to traction / compression / shearing / flaming of the materials from which the ventilation structures of the main ventilation station are built.

In Chapter IX, entitled *"Determination of critical areas in relation to the risk of explosion at the level of Lupeni mine"*, a detailed analysis of the ventilation network was carried out with the presentation of the explosive atmosphere, the accumulation areas and the potential sources of the underground explosions, respectively the analysis explosion risk related to the Lupeni mine.

In the particular case of the Lupeni mine ventilation network, an analysis was made of the possible environments that could lead to the occurrence of the explosion phenomenon, respectively, of the sources that can generate explosion phenomena for each mine area and mining work.

The Explosion Risk Analysis was performed by - explosion risk analysis and assessment, the mining hazard specific risk analyser, the relevant risk analyser, and the risk level assessment.

As a result of the explosive risk assessment, at the level of the Lupeni mine ventilation network, a number of 10 critical areas were assessed, ranging from medium risk to very high levels.

In Chapter X, titled *"Simulation of explosion phenomena at the level of Lupeni mine ventilation network"*, there is a simulation of explosion-type phenomena at the level of the Lupeni mine workings network.

For the simulations to determine the possible effects of an explosion phenomenon, the results of the explosion risk analysis carried out on the complex Lupeni mine workings network, updated with Ventsim Visual Advanced, were taken into account.

Out of the ten vulnerable zones obtained from the explosion risk analysis, the vulnerable zone at the level of the Stope with undermined bank 7C / 3 / IV, 320 m elevation, branches 374-375.was chosen.

For the simulations, in relation to the intensity of the explosion phenomenon, the following structure was chosen:

- low intensity explosion - 2 bar;
- medium intensity explosion - 6 bar;
- high intensity explosion - 10 bar;

In Chapter XI *"Final Conclusions, Own Contributions"* I outlined the thesis's conclusions and personal contributions.

Here are some of my personal contributions:

- in the scientific paper, we presented technical aspects related to the mining microclimate specific to the underground coal mining in order to obtain a high degree of comfort of labour;
- we have extensively presented different methods of calculation and dimensioning of natural draught specific to the deep ventilation networks, respectively with a significant elevation difference between the mine workings and the surface;
- also, in the scientific paper I presented how to conduct the general ventilation for the case of complex ventilation networks focusing in particular on the types of fans that can be used;
- in the scientific paper, we synthesized techniques for solving the ventilation networks;
- to solve the complex Lupeni ventilation network, we analysed the specialized programs used for this purpose: VentSim Visual Advantced, 3D-CANVENT, VentPri, VentGraph, Vuma-3D, VentPC, MineFire, DuctSIM and CLIMSIM;
- in the doctoral thesis, we analysed and solved the complex ventilation network connected to the Lupeni mine with 3D-CANVENT;
- in the scientific work, for the modeling, solving and optimization of the Lupeni mine's ventilation network, we used the following steps:

- obtaining general topographic maps from the baseline and horizons, respectively spatial air maps;

- identification of nodes and branches in the ventilation network;

- obtaining the geodetic coordinates of the identified nodes;

- carrying out measurement campaigns at the level of each branch, measurements that included: determination of the aerodynamic and state-specific parameters of each branch;

- data processing in a manner compatible with the program database;

- the introduction of technical data on the geodetic coordinates and the design of the ventilation network;

- the introduction of the technical data resulting from the measurements into the program database;

- levelling the ventilation network;

- solving the ventilation network;

- optimization of the ventilation network;

- obtaining results in tabular form;

- in the doctoral thesis, we have developed the modeling, solving and optimization of the updated ventilation network of the Lupeni mine with the VentSim Visual ADVANCED program.

For this we used the data bank of the 3D-CANVENT program and all the above-mentioned stages;

- for a thorough understanding of the explosion phenomenon, we have extensively presented the technical notions of explosion risk;

- in the scientific paper, we presented the explosive environments, the accumulation areas and the sources of initiation specific to the underground coal mines;

- at the same time, we analysed the types of explosions that can occur underground;

- I have carried out a thorough analysis of the effects of the underground explosions from a dynamic, thermal and chemical point of view;

- we have analysed the changes occurred at the level of a ventilation network in the conditions of occurrence of an explosion phenomenon, especially at the level of the ventilation constructions, respectively at the level of the underground microclimate;

- for a detailed understanding of the effect of an explosion on the main ventilation station, we conducted a thorough analysis of the effect of an explosion on the mine working of the main ventilation station;

- we also conducted an analysis of the transient phenomena present during the occurrence of an explosion phenomenon;

- for the purpose of identifying critical areas in relation to the risk of explosion, we have carried out a detailed analysis at the level of the Lupeni mine ventilation network, in order to determine the explosive environments, the accumulation areas and the sources of initiation specific to the underground mine workings;

- in the doctoral thesis, we carried out a professional analysis of the risk of explosion at the level of the entire Lupeni mine ventilation network;

- in the scientific work, as a result of the identification of the critical areas resulted from the explosion risk analysis, we carried out, based on the complex ventilation network of the Lupeni mine, updated, modeled, solved and optimized, the simulation of a virtual explosion phenomenon of low intensity-2 bar;

- we have also simulated a virtual explosion phenomenon of medium intensity - 6 bar;

- at the same time, we have simulated a virtual explosion phenomenon of high intensity - 10 bar

- in the scientific paper, we carried out the simulation concerning the possibility of ventilation through natural circulation of the complex ventilation network of the Lupeni mine, under the hypothetical conditions of eliminating the driving force generated by the main ventilator, under the virtual conditions of producing a 10-bar high intensity explosion;

Any scientific approach is perfectible and may involve improvements, refinements and additions.

The results of the scientific approach can be specifically applied to the Lupeni mine's ventilation network, but the technique and the means used can be applied to any ventilation network, regardless of its complexity.