Updated analysis of the complex ventilation network of the Lupeni Mine

Florin Rădoi[1*], *Corneliu* Boantă[1], *Androo Paul* Gherghelaș[2], *Daniel Cosmin* Vitan[3], and *Ovidiu-Bogdan* Tomuș[3]

[1] National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea Street, Petroșani, Hunedoara, Romania;
[2] GIS MAPPING TOPO SRL, 27A Alexandru Ioan Cuza Street, Vișeu de Sus, Maramureș, Romania;
[3] University of Petrosani , 20 University Street, Petroșani, Hunedoara, Romania

Abstract. The ventilation system is a key component in ensuring safe working conditions in underground mining operations, especially in coal mines such as the Lupeni Mine. This paper presents an updated analysis of the mine's ventilation network, with the primary objective of identifying existing inefficiencies and proposing technical solutions to optimize airflow throughout the underground workings. Based on topographic data, in-situ measurements, and simulations performed using specialized software, the study evaluates the main ventilation routes, pressure losses, air volume distribution across different areas, and the performance of the ventilation equipment in use. The results highlight the presence of poorly ventilated sectors, particularly in active work zones and areas prone to gas accumulation. Following the analysis, several improvements are proposed, including the reconfiguration of ventilation paths, modernization of ventilation fans, and implementation of an automated monitoring system for underground atmospheric parameters. This study contributes to enhancing worker safety, improving energy efficiency, and aligning the ventilation infrastructure with current technical and regulatory standards in the mining industry.

1 Introduction

Underground mining operations are carried out in a complex and often hazardous environment, where atmospheric control plays a crucial role in preventing accidents and protecting the health of workers. In coal mining, particularly in deep underground mines like the Lupeni Mine, the risks associated with gas emissions (especially methane), flammable dust, and oxygen deficiency are significant. These risks require the implementation of an efficient and well-adapted ventilation system, tailored to the evolving configuration of the mine's infrastructure.

    Lupeni Mine, located in Romania's Jiu Valley coal basin, is one of the oldest and most important coal mining operations in the country, with a history dating back to the second half of the 19th century. Over time, the structure of the underground workings has expanded

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[*]Corresponding author: florin.radoi@insemex.ro

considerably, reaching great depths and a high degree of complexity in its network of galleries, shafts, and frontal longwells. These developments, combined with the physical and moral wear of equipment, have led to decreased efficiency of the ventilation system and the emergence of functional deficiencies in certain areas. In this context, a thorough and updated technical analysis of the mine's ventilation network is essential, taking into account recent structural changes and advancements in ventilation technologies. The importance of this endeavor is reinforced by new requirements regarding occupational safety, energy efficiency, and environmental compliance, imposed both at the national and international levels.

The present paper aims to assess the functional parameters of the Lupeni Mine's ventilation system by correlating practical field data with theoretical modeling and numerical simulation. The analysis focuses on air circulation routes, fan capacities, pressure losses, airflow distribution, and system behavior under various operational conditions. Additionally, the study considers the impact of recent geological and structural modifications on airflow dynamics and the emergence of potentially hazardous zones. Based on the findings, technical proposals are formulated for optimizing the ventilation system, including route reconfiguration, equipment modernization, and the implementation of an automated monitoring system for underground atmospheric parameters. This analysis seeks not only to improve the operational performance of the mine but also to align it with current safety and energy efficiency standards, thus contributing to the long-term sustainability of mining activity in the region.

2 Establishing input data for the analysis of the ventilation network

The Lupeni Mining Operation was equipped with 2 main ventilation stations, Shaft 1Est and Central Shaft. The general ventilation of the Lupeni mine, [1, 2], in the current situation, is carried out ascending under the influence of the general depression created by the main ventilation station Central Shaft, equipped with two ventilation units type VOKD 1.8. The entry of fresh air into the underground is done through the following works: Ştefan shaft; shaft no. 12; Skip shaft; horizontal coastal gallery 650; South auxiliary shaft; shaft 1Est, generally presented in figure 1. The direction of air currents from the underground is done through ventilation constructions.
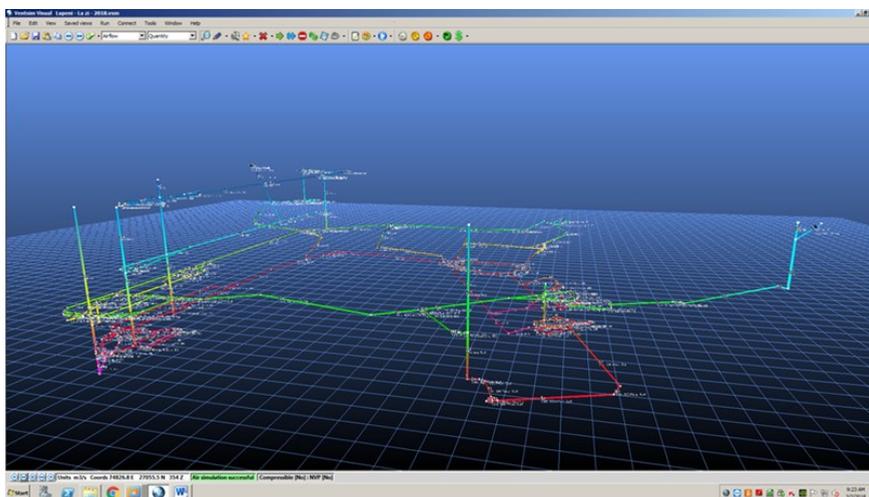

Fig. 1. The ventilation network of the Lupeni mine

To solve the ventilation network of the Lupeni mine, [3], the database belonging to the VENTSIM DESIGN program was used and used in solving the ventilation network, [4, 5], the geodetic data specific to the structural changes of the ventilation network, [6, 7], respectively the flow-metric and depression-metric measurements performed in situ.

To solve the ventilation network of the Lupeni mine, a number of 343 nodes and 449 branches were introduced [8].

The following results were obtained from solving the ventilation network of the mine:

- the air flow rate on the fresh air supply circuit at elevation level 650, 480, 400, 300, branches with unique number 587, 267, 481, 410, 343, 115, 288, 779 was 55.5 m^3/s.;

- the air flow at the level of the frontal cut-off with undermined coal bank Panel 9, str. 3 bl. V, elevation 460, with unique number 823, was 4.3 m^3/s.;

- the air flow at the level of the frontal cut-off with undermined coal bank Panel 7C, str. 3 bl. IV, elevation 320, with unique number 807, was 5.6 m^3/s.;

- the air flow at the level of the complex mechanized frontal cut-off panel 2C, str. 3 bl. IV elevation 360, with unique number 796, was 6.3 m^3/s.;

- on the exhaust circuit of the foul air related to the frontal cut-off with undermined coal bank Panel 9, str. 3 bl. V, elevation 460, with unique number 228, it was 8.5 m^3/s.;

- on the exhaust circuit of the foul air related to the frontal cut-off with undermined coal bank Panel 7C, str. 3 bl. IV, elevation 320, with unique number 817, it was 9.2 m^3/s.;

- on the exhaust circuit of the fouled air related to the frontal complex mechanized fallout Panel 2C, str. 3 bl. IV elevation 360, with unique number 629, was 15.5 m^3/s.;

- at the mine level, the branch with unique number 568, the flow rate was 55.5 m^3/s.;

- at the station level, the branches with unique number 569, the flow rate was 56.8 m^3/s.

3 Updating the ventilation network

The underground mining works are ventilated under the depression of the main fan station Central Shaft, [9], which is equipped with 2 (two) axial fans, VOKD 1.8, with a nominal flow rate of 6000 m^3/min, [10]. Currently, the main fan station Central Shaft achieves a flow rate of 2649 m^3/min; ($\alpha = 30°$). To solve the ventilation network of the Lupeni mine, the specialized program VENTSIM DESIGN was used, respectively the database belonging to the CANVENT program was used. After entering the geodetic coordinates into the database of the VENTSIM DESIGN program, it automatically calculates the spatial distance between two consecutive nodes and instantly draws the specific branch. After modeling the ventilation network in 3D Solid system, the specific technical data, namely the profile and shape of the mining works and ventilation constructions, [11, 12] are introduced for each branch. The next stage consisted of introducing the parameters related to the fans within the main ventilation stations, [13], by introducing into the program database the aerodynamic parameters specific to each fan according to the individual characteristic curves.

To solve the updated network of the Lupeni mine, a number of 47 nodes, respectively a number of 54 branches, were removed from the ventilation network, spatially presented in figure 2. In order to update the ventilation network, the following branches were removed from the network:

- gallery blind Shaft no. 15, elevation 400, branches: 186-187; 187-188; 188-189; 189-190; 190-191;

- delta access plan Shaft 1 East elevation 400, branches: 191-285; 225-286;

- ventilation circuit Shaft 1 East, branches: 191-286; 286-287;

- access plan Shaft 1 East, branch 287-288;

- transverse gallery Shaft 1 East, branch 288-289;

- ventilation shaft 1 East, branches: 289-290; 290-291; 290-292;

- gallery transport Panel 2/3/V, branches: 294-295; 295-306; 306-307;
- head gallery Pan. 2C/3/V, branch 304-305;
- ventilation gallery Pan. 2C/3/V, branch 305-319;
- transverse gallery Pan. 3/3/V, branch 315-316;
- directional gallery Pan. 3/3/V, branches: 316-317; 317-318; 318-319;
- directional ventilation gallery Pan. 3/3/V, branches: 319-324; 324-325; 325-326;
- ventilation gallery Pan. 2C-7C, branch 296-378;
- access transport gallery Pan. 2C-7C/3/IV, branches: 295-389; 389-296; 296-385;
- Panel access gallery 2C/3/IV, ramifications: 385-386; 386-387; 389-390;
- Panel gallery 2C/3/IV, branch 387-388;
- Panel frontal longwall 2C/3/IV, branch 388-390;
- Panel gallery 2C/3/V, branch 391-304;
- Panel frontal longwall 2C/3/V, branch 390-391;
- access gallery Panel frontal longwall 7C, branch 385-370;
- access gallery Panel frontal longwall 7C, branch 370-371;
- base gallery Panel frontal longwall 7C/3/V, branch 371-372;
- base gallery Panel frontal longwall 7C/3/V, branch 372-373;
- base gallery Pan. 7C/3/V, branch 373-374;
- Panel frontal longwall 7C/3/V, branch 374-375;
- Head gallery Pan. 7C/3/V, branches: 375-376; 376-377;
- Head gallery Pan. 7C/3/V, branches 377-378;
- Collector gallery Pan. 2C, branches 378-305;
- Base gallery Pan. 9C/3/5, branches. 379-380; 380-381;
- Panel frontal longwall 9C/3/V, branches 381-382;
- Head gallery Pan. 9C/3/V, branches: 382-383; 383-384.

Also, a number of 8 nodes and 11 branches related to the frontal longwall Pan 7C bis, str. 3, bl. IV, oriz. 300 were reintroduced into the mine's ventilation network, as follows: 295-315; 315-316; 316-317; 317-318; 318-319; 319-324; 324-325; 315-325; 325-304; 304-306; 295-306. Four constructions were placed to separate fresh air from stale air on branches 315-325 and 295-306, the data of these changes being presented in figure 3.

The central area of the mine, where the Stefan Shaft, the Skip Shaft and Shaft no. 12 are located, is shown in figure 4.
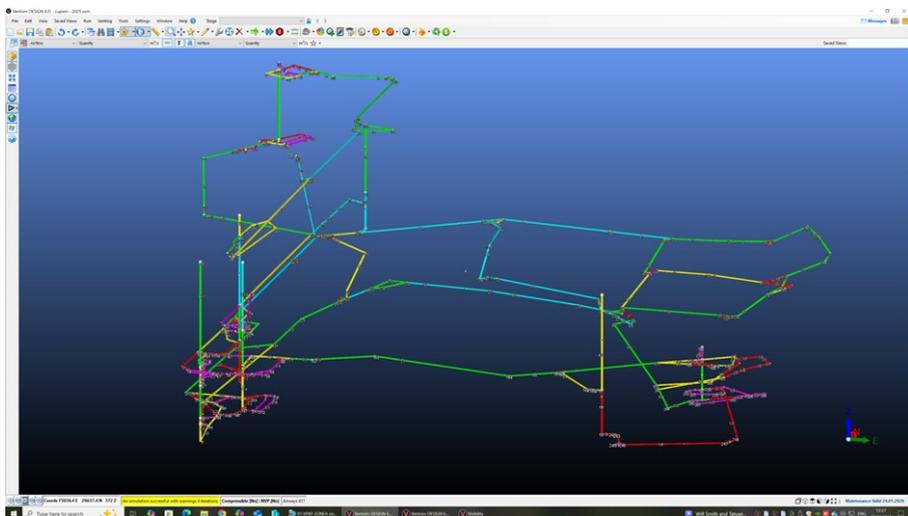

Fig. 2. The ventilation network of the Lupeni mine in 3D Solid system
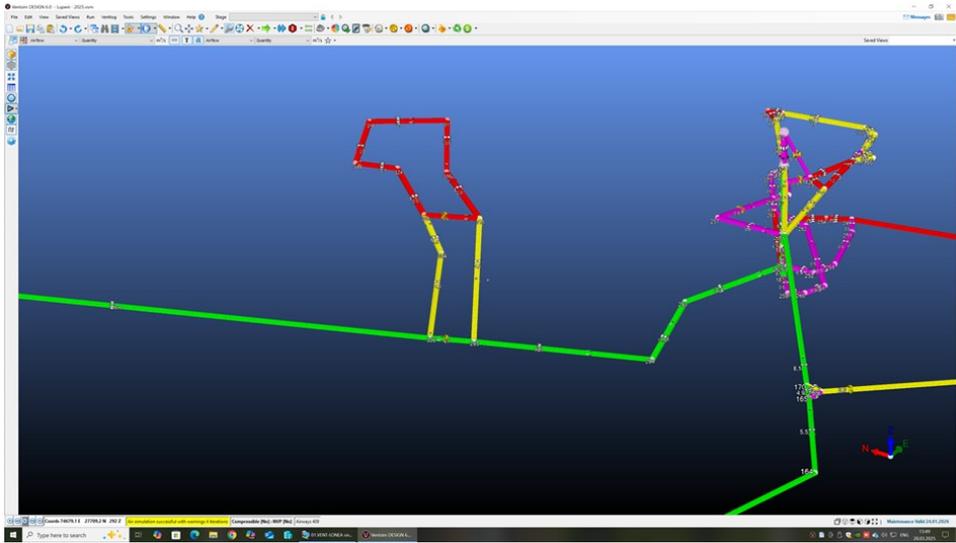
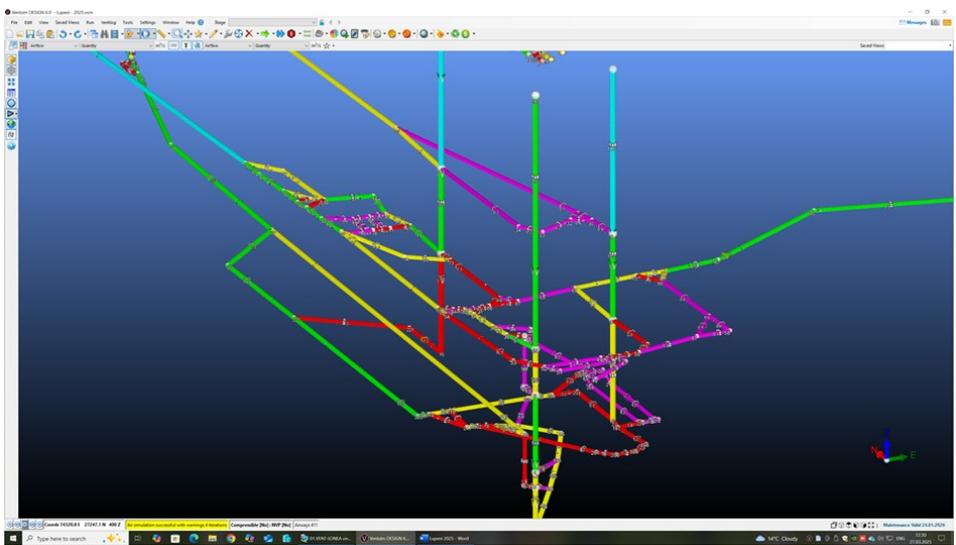**Fig. 3.** Frontal longwall Panel 7C bis, Bl. IV, rice 300

Fig. 4. The central area of the mine – Shaft Ștefan, Skip Shaft and Shaft No. 12

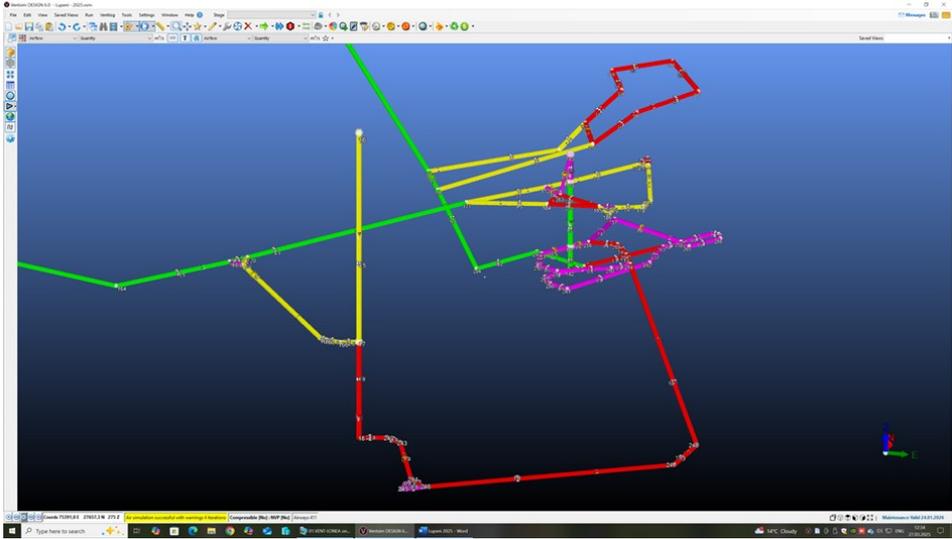Figure 5 shows the diagram of the South Auxiliary Shaft and Blind Shaft no. 15 area.

Fig. 5. Area related to South Auxiliary Shaft and Blind Shaft No. 15

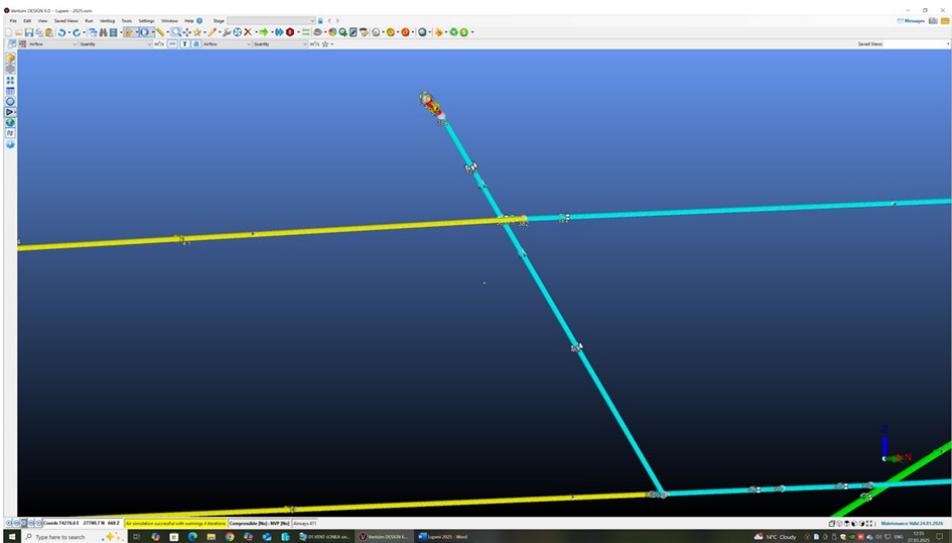Figure 6 shows the diagram of the Central Shaft, with the main ventilation station.

Fig. 6. Central Shaft related area – Main ventilation station

Analyzing the updated ventilation scheme of the Lupeni mine, the following aspects mainly resulted:
- the air flow rate on the fresh air supply circuit at the level of elevation 300, branches 71-162, 224-225 and 246-247 is 20.9 m^3/s.
- the air flow rate on the fresh air supply circuit at the level of elevation 400, branch 95-96 is 14.1 m^3/s;
- the air flow rate on the fresh air supply circuit at the level of elevation 480, branch 35-378 (air short-circuit) is 4.1 m^3/s;
- the fresh air flow rate on the coastal gallery at the level of elevation 650, branch 29-382 (air short-circuit) is 4.1 m^3/s;

- the total fresh air flow rate introduced at the level of the ventilation network was 43.2 m³/s;
- The air flow rate at the level of the frontal longwall with undermined coal bank Panel 7C bis, Bl. IV, elevation 300 is 10 m³/s (branch 264-293).
- the air flow rate on the exhaust circuit of the frontal longwall with undermined coal bank Pan. 7C bis, Bl. IV, elevation 300 is 10 m³/s (branch 366-367);
- At the mine level (branch 383-384) the air flow rate is 43.2 m³/s.
- At the level of the main ventilation station Central Shaft (branch 384-385) the air flow rate is 44.2 m³/s.

4 Conclusions

The E.M. Lupeni branch has six mining works connecting to the surface, of which four are vertical shafts with the role of fresh air inlet and one is a follower with the role of exhausting stale air. The mining works network related to the Lupeni mine extends in depth to the level of five active elevation (horizons). The main ventilation station is equipped with two VOKD 1.8 type fan-motor aggregates.

The mine's ventilation network is complex, with a relatively small number of air control and regulation structures, namely 9 groups of ventilation structures.

The mine's ventilation network, developed vertically at the level of five main active elevation, is served by the main ventilation station Central Shaft which, in relation to the main fresh air entry routes, is located in the central western area.

The mine ventilation scheme was created based on the topographic plans for each elevation, establishing a number of 408 nodes and 408 branches.

In order to solve the updated network of the Lupeni mine, a number of 47 nodes and 54 branches were removed from the ventilation network.

A number of 8 nodes and 11 branches related to the frontal longwall Panel 7C bis, str. 3, bl. IV, elevation 300 were reintroduced into the mine ventilation network.

Following the update of the mine ventilation network, the following results were obtained:
- the air flow at the level of the frontal longwall with undermined coal bank panel 7C bis, is 10 m³/s;
- at the level of the main ventilation station Central Shaft the air flow is 44.2 m³/s.

The solution of the ventilation network aimed at achieving the necessary and measured air flows according to the Annual Ventilation Project, at the level of the frontal longwalls, the main ventilation circuits, and the main ventilation station.

Following the update of the ventilation network related to the Lupeni mine after a period of five years, it was observed that the structure of the network had undergone major structural changes. At the same time, a change in the number and spatial position of the walls was also noted.

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