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The coal exploitation in the Jiu Valley between the strategic resource and social impact

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Abstract: The paper deals with the exploitation of coal in the Jiu Valley, starting from the mining tradition and the future of coal. On the other hand, the shortcomings of the coal exploitation are looked over, which have focused the public's attention many times through the collective injuries produced in the Jiu Valley. The stages of restructuring the Hunedoara Energy Complex and all the challenges in its evolution after 1989 are analyzed in terms of economic aspects. Dynamic phenomena in coal exploitation are major hazards and safety concerns related to methane present in longwall face goafs. Effective management of methane from coal mines can also have the benefit of contributing to reduced or minimized GHG emissions and to reduce explosion risk by preventing the occurrence of explosive mixtures and by rapidly diluting them to safe concentrations. In this respect, the possibilities of evaluation and optimization of the ventilation system by computerized methods were reviewed.

Keywords: coal mining, energy, methane, risks, geodynamic phenomenon, accidents

1. The international context

Global primary energy consumption grew strongly in 2017, led by natural gas and renewables, with coal's share of the energy mix continuing to decline is noted by BP Statistical Review of World Energy 2018 [1].

However, coal consumption increased by 25 million tons of oil equivalent (Mtoe), or 1%, the first growth since 2013. Coal consumption grew for the first time in four years, it shown in same Report [1]. Consumption growth was driven largely by India (18 Mtoe), with China consumption also up slightly (4 Mtoe) following three

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successive annual declines during 2014-2016. World coal production grew by 105 Mtoe or 3.2%, the fastest rate of growth since 2011. Production rose by 56 Mtoe in China and 23 Mtoe in the US. Coal remains the world’s dominant source of power, with a share of 38.1% in 2017, almost as much as natural gas (23.2%) and hydroelectricity (15.9%) combined, which sit in second and third positions. Over the same period, nuclear’s share declined by 3.4 percentage points while coal lost 3.1 percentage points. [1]

The coal plays an important role in the European economy. Over 25% of EU electricity comes from coal, in this industry and related businesses working more than 200.000 people. Balancing the need for coal with the environmental impact is a challenge for both the coal industry and European policy makers.

The economic arguments for coal have recently changed the balance in its favour. After years of decline the demand for coal in the EU has started to rise again. On the other hand, many coal power plants will face closure due to new air pollution limits. Coal production in EU shall be affected by the stage of granting state aid for the closing of coal mines. [2]

Furthermore, the policies to reduce the greenhouse emissions have profound implications in the coal industry. The only way to reconcile the use of coal in the power system is a greater flexibility of approach and efficient absorption of carbon dioxide.

The European Union is the third coal region, after China and North America. Each year, there are extracted about 130 million tons of coal and other 210 million tons are imported. 25% of electricity comes from burning bituminous coal and brown coal. [2]

In this context, in our country, the energy transition is saying its word, leaving for two major challenges: to keep coal in the energy mix and to fit within the limits imposed by the EU's rules of the large coal burning installations.

2. History of coal exploitation in the Jiu Valley

The country has a long coal mining tradition, stretching back over 150 years. Coal was undoubtedly the primary fuel of the first phase of industrialization from Romania. Increasing demand of coal led to open bigger mines, the most important of which were in Banat and the Jiu Valley Basin. Nonetheless, these resources fell short and Romania continued to import coal throughout the period.

Mankind’s energy consumption skyrocketed between the wars, although some changes in the use of resources had occurred even before the First World War. The role played by petroleum and its derivatives increased, as that of electricity and natural gas. Coal was still the number one resource, although it was in decline. The same evolution can also be observed in Romania, albeit with a slight time lag, explained by a relative economic decrease and the characteristics of the natural resources. [3]

Coal production increased in the 1920s, and then registered lower levels. Coal as an energy source remained significant, but the most dynamic resources were petroleum and natural gas. Coal production also witnessed noticeable growth. [3]

The first exploitation of coal deposits from the Jiu Valley was carried out in 1848, but the systematic exploitation of coal could not begin because of the lack of transport infrastructure.

As to the history of the Jiu Valley mining area, for more than 150 years since the opening of the first mining exploitation in 1859 in Petrila, billions of tons of coal have been extracted. In 1867 the construction of the Simeria Petrosani railway line began, thus making it a modern and fast means of transportation, the locomotives to consume coal from the Jiu Valley. In 1872, the first steam extraction machine was installed at Petrila and in 1890 the road Petrosani-Targu Jiu was opened. During this period, coal mining works at Lupeni, Vulcan, Aninoasa are opened by various companies. With the development of coal mining, the need for electric power has also arise. [4]

In Romania, total bituminous coal resources are situated in the Valea Jiului coal basin are estimated to be 2446 million tons of which 252.5 million tons are commercially exploitable within the currently leased areas, although as little as 11 million tons might be economically recoverable. Proven reserves of lignite total 280 million tons, with a further 9640 million tons of resources. Of these deposits, 95% are situated in the Oltenia mining basin where more than 80% can be surface mined. The remaining lignite deposits have low economic potential, explaining why extraction in most other areas has stopped. [5]

Romania's entire hard coal and lignite output is used for heat and power generation. At the end of 2015, the total licensed net capacity of installed generation was 20419 MW: coal 4925 MW (24.1% – 1148 MW hard coal and 3777 MW lignite), natural gas / fuel oil 3571 MW (17.5%), hydropower 6339 MW (31.0%), nuclear 1 300 MW (6.4%) and renewable 4 284 MW (21.0%), mostly wind turbines. Peak demand is between 8000 MW and 8500 MW, indicating an overcapacity in generation and offering the opportunity for significant exports of electricity. [5]

The power generated to the National Energy System SEN in 10 February 2019 on the primary energy sources is shown in Fig. 1, with a total of 7554 MW. The share of coal represents 21.1%. [6]

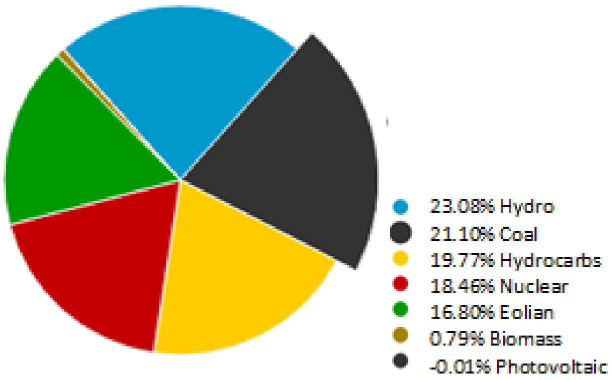

Fig. 1. Production of energy from primary sources.

Back in January 2011, the National Hard Coal Company had seven underground coal mines (Lonea, Petrila, Livezeni, Vulcan, Paroseni, Lupeni and Uricani). In September 2012, these mines were merged with Thermal Power plants to create the Company Complexul Energetic Hunedoara CEH, a state-owned electricity and heat producer headquartered at Petrosani. The company accounts for approximately 3% of Romanian electricity generation, with a capacity of 1225 MW and about 6300 employees. [7, 8]

The main consumers of bituminous coal are Paroseni Thermal Power Plant TPP at (150 MW) and Mintia TPP (1075 MW). Indigenous bituminous coal production has the advantage of ensuring a long-term supply for these power plants. However, bituminous coal mining in Romania faces complex geological conditions, not easy to exploit it, making profitable mining difficult. [7]

The results of an economic analysis determined that the Petrila, Paroseni and Uricani mines in the Jiu Valley do not have viable prospects and so they were included in a closure plan. State aid was agreed by the European Commission in February 2012, being intended to facilitate these closures. Meanwhile, the CEH entered into insolvency in June 2016. Restructuring continues according to Council Decision 787/2010/EU with aid approved by European Commission decision C(2015) 2652.

However, four mines scheduled to continue after 2018 and also from the power plant 385 MW of the 1225 MW currently installed capacity will remain, 150 MW unit at Paroseni TPP, modernized in 2005, and the 235 MW unit 3 at Mintia TPP, modernized in 2009. So, this means that bituminous coal mining and hard coal-fired power generation capacity in Romania will continue after 2018. [7]

3. The future of coal from risks and the social impact

The so-called “public”, that is, the people who do not work in coal-mines, have the impression that, next to working in an ammunition or powder factory, there is no more dangerous calling than that of the coal-miner. And the public is right. At irregular intervals the whole world is shocked by the reports of mine explosions which have cost the thousands of workers lives. Such mine catastrophes are so common that explosions costing less than 100 lives attract little notice. [8]

And still, our days the coal-miners lose their lives frequently through mine explosions.

We list below a number of most important accidents from the Jiu Valley coal mines, not in order to gloat over harrowing details, but because these shows the danger of works in mining against neglected safety conditions of workers in the coal-mining industry on economics reasons. It is customary for the mine owners and officials to blame all accidents on the "carelessness," "neglect," or the "ignorance" of the mine workers, but if such subterfuge is too raw to pass muster before public opinion, they blame it on their "God" or "Providence." However, experience has proven that where strict rules have been adopted and enforced, "carelessness, neglect and ignorance" disappear as if by magic. [8]

But it is not only that about thousands of people lose their lives every year in mines accidents all over the world, but behind of thousands of coal-mine workers comes the poverty of their families, thousands of desperate miners' widows and miners' children who are thus thrown upon in a unfriendly world.

The causes of accidents in coal mining can be classified as follows [8]:

1. Falls of Roof (Coal. Rock, etc.)
2. Falls of Face or Pillar Coal
3. Mine Cars and Locomotives
4. Gas Explosions and Burning Gas
5. Coal Dust Explosions (including gas and dust combined)
6. Explosives
7. Suffocation from Mine Gases
8. Electricity
10. Mining Machines
11. Mine Fires (burned, suffocated, etc.)
12. Other Causes

Tragic accidents have occurred since the early years of mining in the Jiu Valley. In April 1922, 82 miners died in the Aurelia mine in Lupeni. The worst accidents in tha last 100 years occurred November 1980 in Livezeni mine in the Jiu Valley, where 53 people died in two consecutive explosions. In November 1972, at Uricani mine there was an explosion that killed 43 people. Between 13 September 1977 and 23 December 1989, 80 miners died and others survived with permanent disabilities and temporary incapacity. After December 1989, 53 mining accidents occurred in Romania. [9, 10, 11]

Development and exploitation of coal deposits requires social acceptance, environmental impact and avoiding the risk of explosion which can be assessed, modeled, and mitigated.

The coal mine managers must be able to identify the risks that lead to underground mine gas explosions, and implement practical strategies to optimize mining safety for workers. Some of these "accidents" may be due to the defective mentality of the workers, but most of them are directly traceable to the technical conditions and of ignoring work safety measures. Accidents credited to carelessness, neglect and ignorance of the workers should be analyzed and the coal-miners should be periodically subjected to the now usual mental tests to ascertain the power of their senses, their quickness of perception, their capacity of judgment, etc.

If they not pass that examination, they should then be sent to a mining school at public expense to learn the theoretical part of mining. This will reduce to a minimum the accidents now charged to "carelessness," etc. [8]

4. Necessity and opportunity of the restructuration of the Company Complexul Energetic Hunedoara CEH

The mining branches own permit for coal exploitation inside the leased perimeters up to 2024. The leased perimeters have a hard coal reserve of 300 million tons. The exploitable coal reserve is of 56 million tons, providing exploitation continuity at current extraction level during the next years. [12]

The coal seams of the Jiu Valley with economic interest are: 3, 5, 7, 13, 15 and 18, which consist of coal beds and sterile intercalations. Currently 3, 5 and 13 seams are being exploited. [7, 12, 13]

The quality parameters from hard coal from the Jiu Valley basin which can represent limitation of coal exploitation from an economical point of view are shown in Table 1.

Table 1. The quality parameters of coal from the Jiu Valley basin [7]

Moisture [%]	0.50-17.20
Ash on dry coal [%]	5.30-49.60
Total Sulphur [%]	1.08-10.94
Calorific value [kcal/kg]	3400- 8100

It can be concluded that coal from Jiu Valley has a high content of ash and Sulfur. Description of coal exploitation methods and technical aspects of coal mining belonging the CEH are shown in Table 2.

Table 2. Technical condition of the coal mining. Description of coal exploitation methods [7]

Description of coal exploitation methods	**Explanations**
Number of exploitation permit (availability period)	for 20 years/in year 2000 obtained
Geological condition of coal deposit	Difficult geological conditions of coal deposits, presence of methane and coal self-ignition tendency. Thickness layer and slop.
Reserves balance A+B+C_1 on 01.01.2015 [thousand tons]	132 212. 609
Open reserve on 01.01.2015 [thousand tons]	4 545.870
The layers under current exploitation	Layers 3, 5, 13
Production estimated in 2015 at CEH [thousand tons]	1340
Long wall of thin layers with tall inclination pillars method	Layers13 and 5
Long wall of thick layers method	Layer 3
Framework method with undermined bed for thick layers and average inclination ($\alpha = 25^0 \div 45^0$)	Layer 3
Exploitation of thick layers in horizontals slices with short long walls, with partial ventilation	Layer 3
Exploitation of thick layers in horizontals slices using long walls	Layer 3

Description of coal exploitation methods	**Explanations**
Exploitation of thick layers with average inclination through undermining behind the front line	Layer 3
Combined exploitation forward-backward under the form of slices with long walls	Layer 3

5. Methane emissions from Coal Mines in Jiu Valley

Methane, CH_4, released during coal mining creates unsafe working conditions in many underground mines around the world, with human fatalities an unacceptable consequence of many methane-related accidents. However, effective gas management is not limited to safety concerns. Methane vented to the atmosphere, especially from drainage systems, is an energy resource lost forever. The resulting emissions also contribute to climate change. [14]

Methane gas, which accompanies coal deposits, is formed simultaneously with coal and also comes out of similar primary substances during the process of carbon production that occurs under elevated temperature and pressure conditions. Methane formation is consequently closely connected with the carbon producing from organic matter that has allowed the transformation of vegetal deposits into various coal qualities; this also depends on the composition of the fermented substance. [14, 15]

The amount of gas absorbed by the coal varies directly proportional to the pressure and inversely proportional to the temperature. During the process of slow oxidation, the oxygen contained by plants determined the release of certain gaseous products, mainly CH_4 and CO_2. [16]

At the same time, the methane gas released in the atmosphere may be used by the mine operators as a primary energy resource in order to cover their own energy requirements, or may be used for trade. [16].

The exploited coal within the Jiu Valley basin release, each year an important amount of methane. This amount is released in the atmosphere both through the central degassing units and through the ventilation units.

Underground mining exploitations liberate methane in the atmosphere, with a concentration of less than 1%, but there are very few attempts at catching and using it. Methane that cannot be captured and used is diluted in ventilation air and emitted into the atmosphere as Ventilation Air Methane VAM. Coal exploitation determines a large amount of methane within the ventilation units of the active mining exploitations of the Jiu Valley Basin, according to Table 1 [16].

All mines in the Jiu Valley have ventilation systems and the total amount of methane emissions from the mining units from Jiu Valley is estimated at 49 million cubic meters per year from ventilation systems and another 4 million per year from other degasification systems. [17]

6. Numerical modeling for ventilation systems evaluation

Effective management of methane from coal mines can also have the benefit of contributing to reduced or minimized GHG emissions. Good safety practice in coal mines is to reduce explosion risk by preventing the occurrence of explosive mixtures where practical, and by rapidly diluting them to safe concentrations (i.e., through ventilation systems). Gas flows from underground coal mines under normal, steady-state conditions are relatively predictable in certain geological and mining conditions, although there is significant variation from country to country. A lack of reliable gas emission prediction methods for deep and multiple-seam minig continues to be a significant challenge due to the complex mining-induced interactions between strata, groundwater and gas. Nonetheless, numerical methods for projecting gas flows, gas capture, ventilation requirements and utilization potential are available and should be used routinely in mine planning. The development of a strategic degasification plan is crucial to the success of both coal bed methane extraction and coal mining. [18]

From a technological perspective, the capture works may be boreholes made in coal beds, boreholes made to voids or cracks created above the coal bed, dams for the isolation of old mining works or drainage galleries made in coal beds. The performance of methane drainage systems can be significantly improved through a combination of proper installation and maintenance, regular monitoring, and systematic drilling. [19]

Using the 3D-CANVENT® Software [19] for underground mine ventilation, the ventilation network can be analysed and modeled, (see Fig. 2). Ventilation system design was based on a model developed for optimizing the performance of the methane drainage systems. The performance of methane drainage systems can be significantly improved through a combination of proper installation and maintenance, regular monitoring and systematic drilling.

A tool used to achieve the simulation of the gas flow can be ANSYS, a multiphysics package. Part of this package, ANSYS Fluent is a powerful instrument providing, amongst others, the availability of parallel computing of the flow issues. [20]

The methane emissions from the coal face, reach value of approximately 0.108 kg/s, approximately 9330 kg/day. The quantities are related to a production of 1,440 tons/day. The mining method geometry with the FEM mesh built with ANSYS software is shown in Fig. 2. The coal seam is 46.9 m long, 25 m wide and 10 m high. The dimensions of coal face are, 2.5 m high, 3 m wide and has the same length as the coal mass [20, 21].

The simulation of the gas flow was obtained with ANSYS software. Fig. 3 shows the results obtained by simulating the CH_4 pressure inside the coal mass along the caving face, galleries and shaft [20].

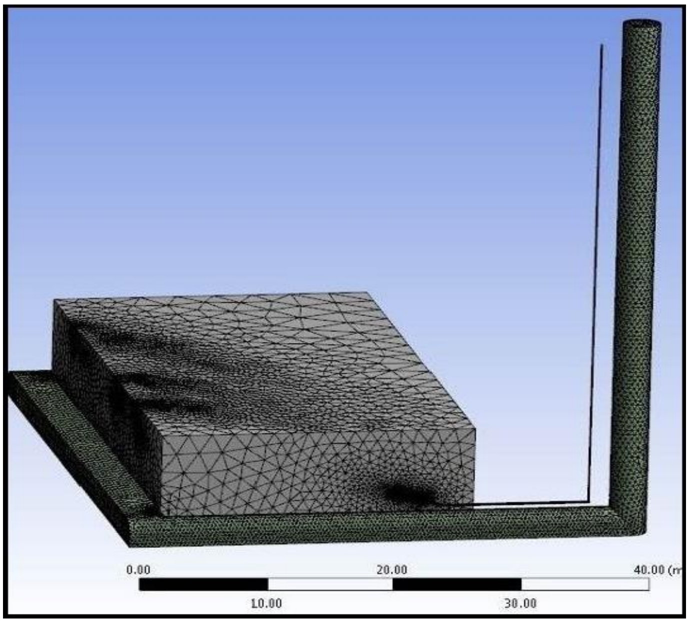

Fig. 2. The geometry of mining method.

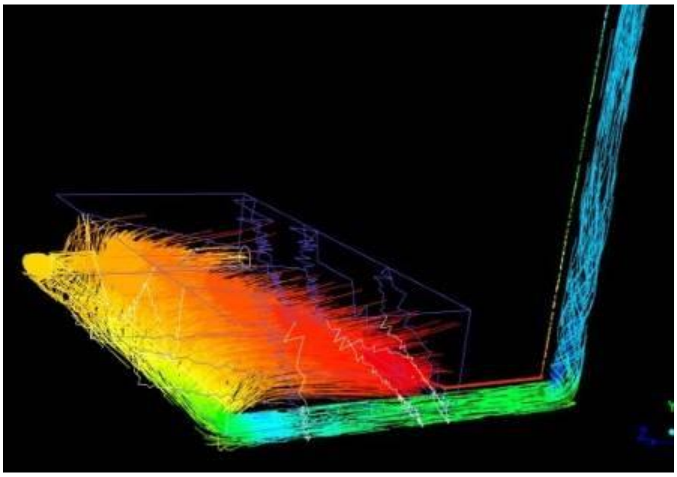

Fig. 3. Path lines of CH4 pressure.

A technical assessment of the ventilation network from a coal mine from Jiu Valley using 3D-CANVENT software was used. Numerical models were developed to design ventilation systems beneficial for both the safety and efficiency of the ventilation process, ensuring optimization of the ventilation system. Also, by using the ANSYS package the real time methane debit and concentrations can be forecasted in coal mines and therefore measures can be taken to improve and adapt the degassing systems to the newly instated conditions as a result of parameter change. [18]

7. Risks factors in coal mining to Jiu Valley Basin

Coal layers exploitation from Jiu Valley basin is achieved in a percentage of 75% by employing the undermined coal bench mining method. The coal output obtained by this method is of about 3 million tons/year. [22]

The productivity obtained with this method is higher than 8 tons / shift. The values of these indicators, strongly recommends this mining method, for general use in the specific conditions met in Jiu Valley basin. However, a time series of technical accidents such as explosions and ignitions of methane gas, roof blowing phenomena or self-ignition of coal and spontaneous combustions have occurred. [23]

Based on researches done by many authors and INSEMEX institute from Petrosani, coal mines managers must be able to identify the risks that lead to underground mine gas explosions, and implement practical strategies to optimize mining safety for workers. The paper offers a framework for understanding the sealed coal mine atmosphere, the safety characteristics that are currently in place, and the guidelines to be followed by engineers to improve upon these characteristics. [11, 24]

In this respect, our research tried to analyze the risk factors related to the mining method application after an expertise of the accident at the Petrila Colliery. [25]

8. Case studies, results and discussions

8.1. Geomechanical characteristics of rocks and coal on collective accident at Petrila mine

In November 2008, at Petrila mine, following an underground explosion, 13 miners lost their lives and 12 were injured. The event took place in the coal face 431 from the layer 3. [25]

The bituminous coal from seam no. 3 at Petrila coal mine are having a pronounced tendency for self-ignition and spontaneous combustion, fact which is confirmed by several self-heating and endogenous mine fire episodes occurred already in this seam area. The hard coal mined at Petrila mine also has high methane content, so values exceeding 15 m^3/ ton were usually met and measured.

Conclusively, we can state that the conditions from the working face 431, Petrila coal mine all the risk factors were gathered, developing consequently a dynamic phenomenon and an explosion in the goaf.

The geodynamic phenomenon from face 431 had occurred due to the instantaneous decline of rocks within the main roof. Because of the piston effect, explosive gases within the gap developed in the third round, were pushed to the working face and on their route they met with the endogenous fire from slice IV, generating an explosion which resulted in 13 deaths and 18 injured workers (see Fig. 4). [25]

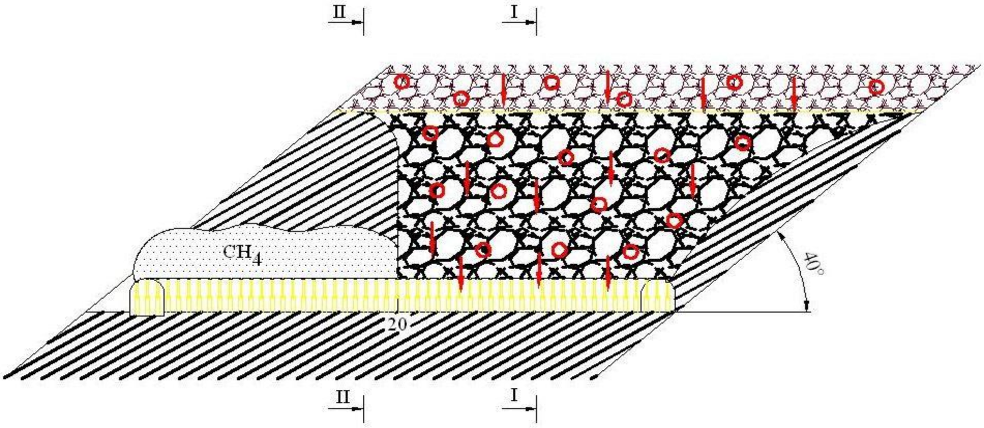

Fig. 4. Cross section through the goaf no.431, slice IV.

The main geomechanical characteristics having implications in producing geodynamical phenomena were determined.

The measured parameters were: the cleave coefficient of structural weakening, specific density and volume, porosity, permeability, compressive strength and traction, the coefficient of strength, cohesion and internal friction angle, elastic and rheological characteristics of coal and surrounding rocks.

In view of assessing the main characteristics of the coal and rocks from the 3-rd seam coal samples have been collected from the several mine working faces of Petrila Colliery and from the direct roof and main roof. After the laboratory tests the following results, listed in Table 3, have been obtained [25].

Table 3. Average values of the physical, mechanical and elastic characteristics of 3-rd coal seam and rocks within the roof

Characteristic	**Coal**	**Direct roof rocks**	**Main roof rocks**
Specific weight $\gamma x10^4$ [N/m^3]	1.45	2.65	2.67
Apparent specific weight $\gamma_a x10^4$ [N/m^3]	1.31	2.58	2.60
Porosity n [%]	9.7	3.5	2.6
Compression strength σ_{rc} [MPa]	9.5	44.1	68
The breaking strength to dries σ_{rt} [MPa]	0.8-1.3	5.6	13.2
Cohesion C [MPa]	1.1-2.5	6.0	20.5
Inner abrasion angle φ	49-58	50	54
Elasticity modulus E [MPa]	5300	8500	10500
Poission Coefficient, μ	0.17	0.2	0.12
Energetic coefficient, I_e		1.32	2.2-3.7

Based on the monitoring data, the pressure (p) and the height of the undermined bench (h) have been calculated for the depths of Petrila working faces and different values of the structural weakening coefficient. They are plotted in the diagram represented in Figure 5. [25]

Based on the monitoring data, the pressure (p) and the height of the undermined bench (h) have been calculated for the depths of Petrila working faces to different values of structural weakening coefficient and we observe that among the parameters that influence pressure value: the depth of the working front towards the (H) surface, the coal cohesion (C), the inner friction angle of the smashed rocks φ and the structural weakening coefficient (Cs) stand out. [26]

8.2. The spontaneous combustion phenomenon

As a consequence of coal oxidation and self-heating of coal mass left in the goaf spontaneous combustions can occur. The oxidation mechanism is based on the theory of chain reactions, by which absorbed oxygen generates meta-stable compounds that dissociate easily, giving birth to phenolic groups, carboxylic or carbonyl and releasing the small quantities of heat. [26, 27]

During the coal oxidation process, the heat release rate varies depending on the amount of oxygen consumed, with a linear relationship between the heat generated and the oxygen consumption.

The distribution of non-uniform stationary temperature is described by the equation:

$$-k \cdot \frac{d^2T}{dx^2} + \frac{j}{x} \cdot \frac{dT}{dx} = q(T) = RQ \qquad (1)$$

The probability of producing the reaction is given by the equation:

$$R = \rho A \exp(-E/RT) \qquad (2)$$

By specifying boundary conditions, the problem is completely defined, but due to the nonlinearity of the term describing the generation of heat, the analytical solution was not determined for such equations. In any case, it has been determined that if E / RTa >> 1 an approximation can be used to solve the equation.

The main factors which are inducing coal self-ignition and combustion are [25, 26, 27]:

- Physical-chemical composition;
- Moisture content, volatile material content, porosity, and specific surface;
- Petrographic composition
- Geological characterization: tilt and layer thickness, deposit’s tectonics, gas content of coal layers
- Losses in the coal mined out;
- Inadequate ventilation system operation.

At the level of the 431-working face from Petrila coal mine, the following spontaneous combustion occurrences took place [25]:

- III subfloor, level - 222.3, 13 February 2005
- II subfloor, level - 231.7, 1 September 2006
- II subfloor, level – 200, 1 October 2007
- III subfloor, level – 200, 16 November 2007.

The assumptions about their occurrence were as follows:

- a reactivation of some older self-heating areas existing in the exploited space;
- the air circulation through the space exploited in the goaf area;
- the coal in the area of the bed and the roof was not completely discharged;
- a low advance speed of the abatement front, ranging from 3.5 to 6 m / month.

Largely, the abandonment of coal in the exploited space and the air circulation through this space predominated, which favored the triggering of coal self-heating.
Spontaneous combustions have occurred were basically generated by coal mass left in the goaf, low face advancing rates and also due to significant air losses within the retreating goaf. [28]

8.3 Gas accumulation

The release of coal bed methane gas is an extremely complex phenomenon that depends on many geomechanical and technical factors and parameters [29]. The amount of methane released from working faces and preparation of working front is due to uncovering new areas, operations and cutting cleaves layers of coal mining under the pressure. A certain proportion of the free methane was evacuated in the return polluted air stream, and another part has been accumulated in the gaps of the exploited seam. Concentrations of methane in the transport and ventilation galleries ranged between 1.68% and 3.46% in the weeks before the explosion. [28]
Ventilation activation, employed in order to reduce the concentration, led to increased losses of air through the use of fire and endogenous fire reactivation. In the gaps resulting from the mining operation, having a volume of 175,000 m^3, methane has accumulated in explosive concentrations [28]. When rocks from the main roof were suddenly undermined, gas has been pushed to the endogenous fire zone.
Analyzing the phenomenon that generated the accident at Petrila mine, the following conclusions were drawn and was compared with also others accident from the Jiu Valley:

- The dynamic phenomenon consisted of strong blast of hot gases and vapors with reduced pressure effects.
- The gases involved were: methane accumulated in the gap in the cracked coal bed and carbon monoxide as a product of endogenous fire in the area;
- Roof rock movements as a result of coal extraction determined the amplification of the failure system that caused air short-circuiting. The variation of the air flows through the exploited space produced the intensification of the self-heating process and the increase of gas accumulations;
- The release of potential energy caused the repeated collapse of the rocks and the sudden expansion of the gas in the formed void area, accompanied by blast and heat to the active mining works.

9. Conclusions

Coal remains the world's dominant source of power, with a share of 38.1% in 2017 and at the beginning of 2019 in Romania there is a share of 21%.

In Romania, total bituminous coal resources are situated in the Jiu Valley coal basin. They are estimated to be 2446 million tons of which 252.5 million tons are commercially exploitable within the currently leased areas, although as little as 11 million tons might be economically recoverable.

The coal mining still has some weaknesses from the point of view of economic and social impact. Unfortunately, nowadays the coal-miners still lose their lives frequently due to mine explosions.

We analyzed the most important accidents which happened in the Jiu Valley coal mines, because these shows how dangerous the mining works are under neglected safety conditions of workers in the coal-mining industry from economics reasons.

Among the accidents causes in coal mining there are: methane and coal dust explosions, which have electrical or mechanical sparks as source of ignition, endogenous fires, carbon dust self-ignition, undetonated explosive staples or charges, overheating of metallic elements from engines, ventilation, and conveyor belts, uncontrolled rock and coal caving, and people falling in the pit.

The main risk factors of generating technical accidents are the geomechanical characteristics of coal and surrounding rocks, the dynamic phenomena occurring in the rocks within the roof of the coal seam, accumulation of toxic and explosive gases in the gaps resulting from the exploitation, the mining methods, the geometrical elements, and the coal's predisposition to spontaneous combustion.

Now, based on advanced software there are possibilities of evaluation and optimization of the ventilation system by computerized methods which can prognosis some abnormal state of underground atmosphere and the gas emission prediction methods can be helpful. In this respect, a technical assessment of the ventilation network from a coal mine from Jiu Valley using 3D-CANVENT software was used.

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