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INFLUENCE OF VARIOUS LONGWALL FACE VENTILATION REGIMES ON SPONTANEOUS MINE FIRE OCCURENCES AND INCREASED GAS RELEASE IN „RASPOTOČJE" MINE OF ZENICA BROWN COAL MINES

Jelena Marković[1.], Refik Kurbašić[2.], Zvjezdan Karadžin[3.], Abaz Velić[4.]

SUMMARY

Brown coal mining conducted at greater depths, characterised with severe mining-geological conditions often results in deviation from the applied mining methods. Experiences gained in mechanised longwall mining of roof plate in deeper parts of Raspotočje mine, using method of roof caving without safety pillars left behind the working panels indicates to shortcomings of the applying mining method. Frequent occurences of spontaneous mine fires, of hazardous gasses well above the limit values, and constant exposure to rock bursts of various intensity resulted in application of three longwall face ventilation regimes: conventional „U" ventilation system, ventilation with gas channel and middle hallway, and separate ventilation of the upper part of the longwall face. This paper presents experience based information gained in a five years period of mining, analysed using one-factor and two factor regression analyses applied to a number of technical-technological parameters (ventilation, mining system, etc) influencing occurences of spontaneous mine fires and increased gas release in various ventilation regimes at longwall face aimed to give basic guidelines for minimisation and elimination of certain hazards.

Keywords: ventilation regime, spontaneous fires, gas release, mechanised longwall.

1. INTRODUCTION

Complex mining conditions in subject mine, especially in deeper parts (below K± 0 m level) chategorised this mine in a group of very complex mines with increased potential hazards, that results from:

- Coal seams are chategorised in a group of seams extremely prone to self-combustion
- Explosive properties of coal dust: p_{max} = 8,6 bar; $(dp/dt)_{max}$ = 394 bar/s; $K_{st,max}$ = 107 m·bar/s)
- Increased content of methane in coal seams (qa= 6,52 $m^3CH_4/t_{čus}$)
- Occurrences of rock bursts were registered below the K ± 0 level, excavation depth was at level 550 – 750, and that is above the critical depths of H_{kr} = 400 m
- Levels of water intake are high (3,0 – 5,0 m^3/min)
- Occurrences of other hazardous gasses were registered as well (CO_2, CO, H_2S, SO_2 and NO_2).

Methane releases occur from coal and accompanying rocks (porous lime stone) in the form of escalation and blowers of various intensity and time duration, mostly in the zone of tectonic disturbances.

Beside the natural conditions, the technical-technological factors have crucial influence on fire occurrences and gas release intensity [1] [8]. Giving that fact, it is necessary to adapt this factors to deposit conditions, i.e. negative occurences related to natural deposit conditions have to be minimised.

1. Prof. Jelena Marković, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Urfeta Vejzagića 2, Tuzla, Bosnia and Herzegovina, jelena.markovic@untz.ba

2. Dr. Refik Kurbašić, Association-FUZIP-e, Sarajevo, Bosnia and Herzegovina

3. Prof. Zvjezdan Karadžin, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Urfeta Vejzagića 2, Tuzla, Bosnia and Herzegovina, zvjezdan.karadžin@untz.ba

4. Mr. Abaz Velić, University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Urfeta Vejzagića 2, Tuzla, Bosnia and Herzegovina, abaz_velic@hotmail.com

Basic influential technical-technological factors include [7]: mining method, ventilation regime, manner and sequence of development works, gob sealing method, advance rate and intensity of mining works, scope of degassing conducted in previous seams.

2. ROOF PLATE MINING IN THE MAIN SEAM OF „RASPOTOČJE" MINE

The deep part of "Raspotočje" mine is one of the mining districts being mined out in the most severe natural conditions occurring in Bosnia and Herzegovina mines.

Roof plate mining of the main seam, Raspotočje mine, was carried out using mechanised longwall face method with retreat advance. Changes in length of working face is determined based on geometry and micro tectonic conditions in the block and occurrences of oxidation processes, that caused shortening of planned working face lengths [10].

Basic properties of mining method are as follows [3]:

- working face length 70-160 m
- minimal mining height 1,70 m
- maximum mining height 3,40 m
- working mining height 3,0 m
- dip angle of working face 6-34°
- productivity 4,50 t/m².

Total thickness of the main coal seam is aprox. 8,30 m, whereas 5,0 m thick coal plate in the floor part was left, except in the parts where floor coal plates were disturbed when crossing over the secondary diagonal faults (thickness of 3,0 m) Figure 1.

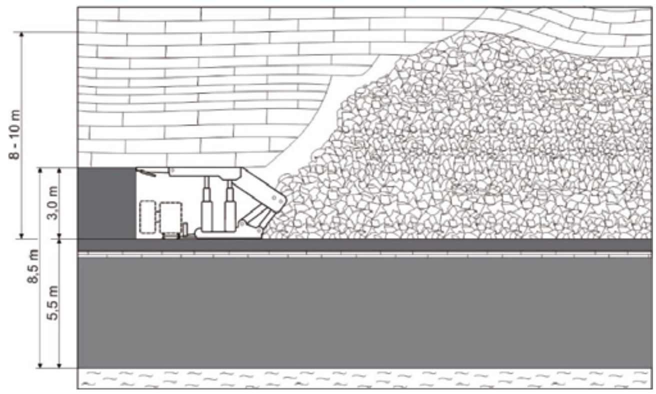

Figure 1. Longwall mining of the roof plate in the main seam

Roof caving was mostly conducted sucessively with working face advance. Rarely, forced blasting was conducted in the case of failled collapsing of the immediate roof plate. Along with advance of working face the entries were closed in the panel (gas channel, middle hallway, connecting gates and other auxilliary rooms), except of transport hallway that was maintained to serve as a gas channel in the next panel.

Arch steel support was dismantled from the gas channel upon passing of working face, for reason of complete caving and to reduce air flow through the gob.

Steel support in the middle hallway and other rooms was replaced with wooden support before arrival of working face, whereas connecting inclines and auxilliary rooms were stowed with filter ash.

3. VENTILATION AND POSITION OF VENTILATION GALLERY AT LONGWALL FACE MINING

Mine ventilation is conducted using mechanical depression method with two axial „Korfman" KGL-220 type fans. Fans are of same characteristics, one used in operation and the second as a reserve. Main mine ventilation is in category of diagonal systems, whereas main district ventilation systems are planned as central and fall in the category for increased fire risk systems due to possible self combustion of safety pillars for district openings (great pressures on openings and significant difference in potentials between entry and exit rooms).

Entry air for longwall face and development workings runs through opening coridors while return air runs down the main ventilation incline. Separate ventilation units (working panels and lower development panels) are separated by an air crossing constructed in the safety pillar for development rooms.

Ventilation of working panel is conducted using conventional „U" system, intake air is driven down the transport hallway to the longwall face whereas air is returned down the ventilation hallway. Lesser quantities of air pass through the connecting inclines in the working panel.

Geological conditions, gass and spontaneous combustion occurences resulted in apllication of 3 ventilation regimes listed below [6]:

«A» conventional „U" ventilation system (safety pillar left toward the gob of the previous working panel)

«B» ventilation with gas channel and central hallway (open contact with the gob of the previous working panel)

«C» separate ventilation of the longwall face upper part (safety pillar left toward the gob of the previous working panel).

3.1. «A» VENTILATION REGIME

This regime was applied for mining of the first working panel in the tectonic blocks and initial parts of the working panels that were longer than previously mined ones. This system is characterised with deep flowing of air through the longwall face gob and by high dependence of gass occurences on air quantity and dynamic of working front (Figure 2) [5] [6]. Figure 3 shows canonical ventilation scheme for the „A" regime.

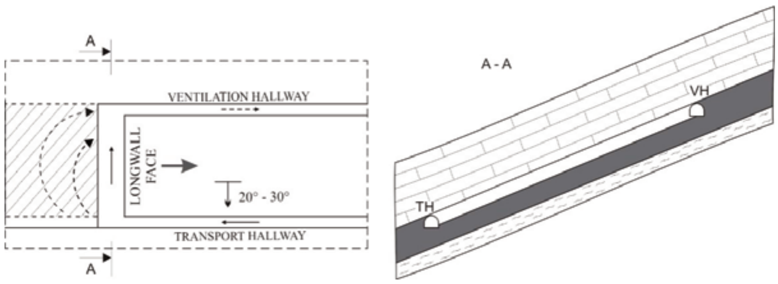

Figure 2. Longwall face mining of the roof plate using conventional ventilation regime

Total length of the longwall working face is 100 m. First problem occurred relating the caving of the immediate roof, after 28 m advance of the face. Upon roof caving, gas release into working face took place along the entire longwall face with methane concentration (CH_4) exceeding 1,0 %, while at the exit from longwall face it exceeded 3,0 %. Gas status went back to normal after couple of days, while 2,0 % methane concentration remained in the top and exit part. During extreme conditions, with drop in barometer pressure, methane release exceed 25.0 m^3/min.

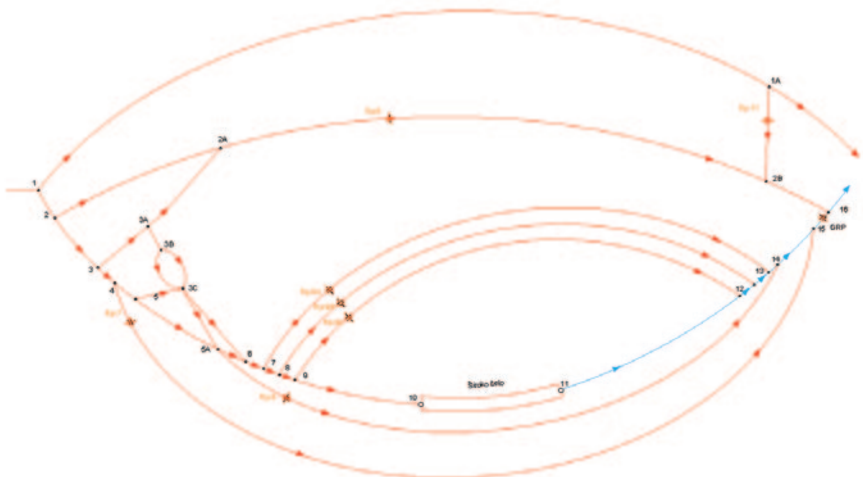

Figure 3. Canonical ventilation scheme – ventialtion regime «A» [5]

Projected longwall face ventilation air quantity is 2000 m^3/min. This required alteration in operation regime of the main fan, i.e. alterations in position of main fan rotor blades. Test operation of the main fan proved stable , up to the blade position on rotor of fan no. 4. This fan operation regime resulted in increase of air quantity from 3200 m^3/min to 4100 m^3/min, with gradual increase of fan depression to 3139 Pa.

Increase in fan depression caused increased activity of methane blowers and increase inflow of CH_4 from the isolation units along the main return air ways. Methane content in front of the main fan reached 50.0 m^3/min, while CH_4 concentration exceeded value of 1.0 %. Finally, parallel operation of main fans set on blade position of fan No 3.5, secured the air quantity of 4500 m^3/min, with simultaneous depression to 2747 Pa.

Rehabilitation of rooms and isolation units on main return air ways was required, in order to reduce methane concentration in front of the main fan, while longwall face operations were conducted with the strict controls of face and air ways (continuous CH_4 control, on site or using methane control station, and removal of electric installations and devices from the entire length of air way.

Installation of hard-rib ventilation pipeline ø 800 mm, from the main ventilation incline to the top of the longwall face, resulted in reduction of methane concentration to the limit values. Pipeline had ø 2,0 m tin funnels mounted at the ends. Funnels fixed in the main ventilation incline was used to create depression in the pipeline, whereas the funnel fixed on the top of the longwall face, at the end of the ventilation hallway toward the gob, was used to capture methane. Quantities and concentrations of gasses in pipeline were controlled regularly, with intention to maintain the methane concentration in pipeline above the 20 %.

Established ventilation regime with gas channel and middle hallway resulted in significant reduction in released methane with simultaneous increase in carbon dioxide quantity (CO_2). Such an exchange of gasses (CH_4 and CO_2) through gas channel secured more favorable mining conditions in the remaining part of the working panel. Problems occurring in the later mining period were related to rock bursts, which became stronger and more intense as the face line approached to the fault zone.

3.2. VENTILATION REGIME «B»

Ventilation regime «B» is the most applied ventilation system in mining operations. It is characterised with an open contact with gob area of previous higher positioned working panel, along the entire active length of the gas channel (20-120 m), and major influence of barometric pressure on gas release and fire occurences [5] [6].

Longwall face ventilation air run down the longwall face to the middle hallway, where air distribution was carried out (figure 4):

- part of the air was driven down the middle hallway between the longwall face and short connecting incline, while
- the remaining air was driven to the top of the longwall face through the gas channel and short connecting incline into the ventilation hallway (joint exit from the longwall face)

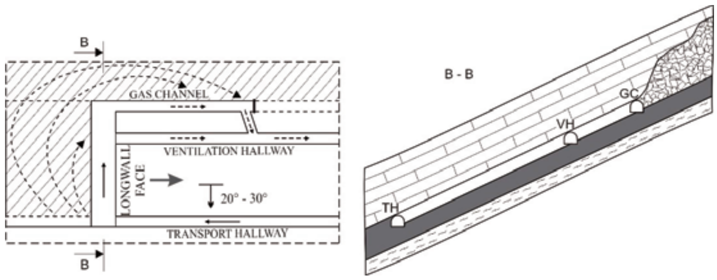

Figure 4. Longwall roof plate mining introducing gas channel and the middle hallway

Figure 5 shows the canonical scheme of the ventilation regime «B». Ventilation loop for air running down the gas channel were set through the short connecting inclines, between the middle hallway and gas channel, that were driven simultaneously with advance of the longwall face. Inclines were driven at distance of 70-100 m, depending on the coal incubation period (3-6 months) and advance of longwall face, i.e. requirement to mine through the open part of the gas channel in the period of three months. Passive part of the gas channel (part between the active part and the end of the panel) is isolated from the active part of gas channel using temporary isolation barriers, while other connections with an actively ventilated part of the mine were sealed using solid stowing barriers.

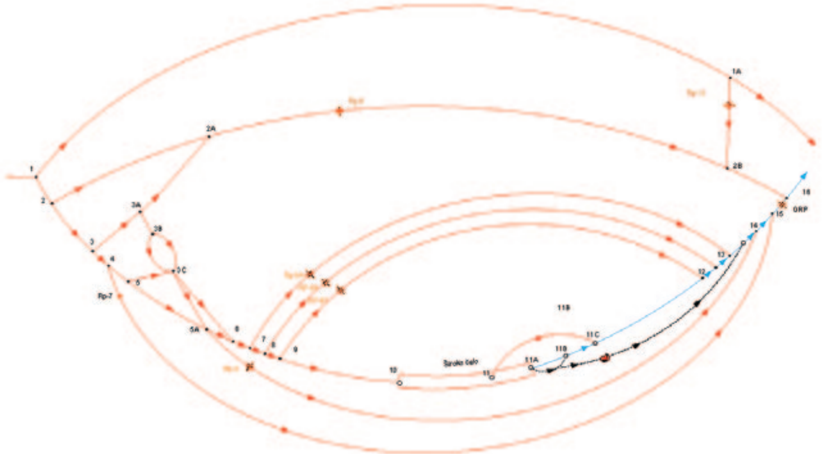

Figure 5. Canonical ventilation scheme – ventilation regime «B» [5]

Apart from air flowing from gob area of the active workings, the air was flowing in from the mined out higher-laying panel as well. Regime is characterised by a swift change of gas concentrations with variation in barometric pressure, resulting in a frequent occurence of high level of gasses in the short connecting incline.

Middle hallway, that served as a ventilation hallway during the development phase, was driven but it was necessary to leave 10 m thick safety pillar toward the transport hallway. Due to the collapsing of safety pillar and occurences of rock bursts it was widen to 25-35 m in the next panels.

Decision on separation from the gob of the higher-lying panels and introduction of separate regime of ventilation of the upper part of the longwall face was made upon 2 occurences of methane inflammation in the area of the active part of gas channel. Source of inflammation in both cases was fire in the gob of the longwall face.

3.3. VENTILATION REGIME «C»

This system was strictly applied in remediation of fires occuring in the gob of the longwall face. It is characterised by reduced inflow of air and hazardous gasses from the gob areas, and lower influence of barometric pressure on release of gasses [5] [6].Separate fan is installed in the lower third of the longwall face, with the end of the pipeline on the top of the longwall face, in order to reduce deeper penetration of fresh air from longwall face into the gob area, Figure 6. Figure 7 shows canonical ventilation scheme for the ventilation regime «C».

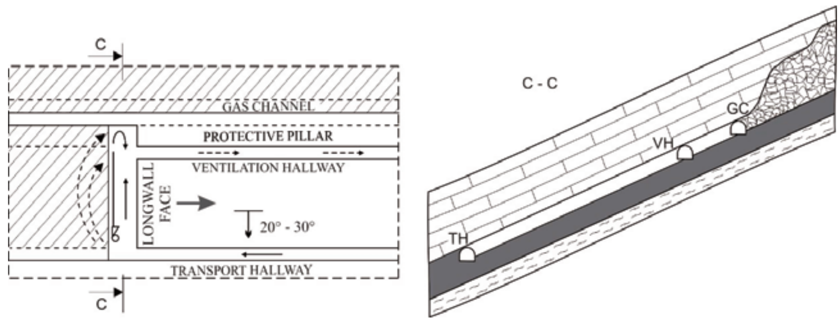

Figure 6. Longwall mining of the roof plate using separate ventilation for the upper part of the longwall face

Large diameter pipelines (ø800 mm), N = 37 kW of power, were used for the separate ventilation of the longwall face to transfer large quantities of air from entry part to the top of the face. Thus the gob was held under the lower depression, resulting in lower releases of gasses and reducing the air quantity required for the ventilation. Lack of this system can be a very long blind part, where, in the case of methane regime of operations and steep angle of longwall face, can occur swiftly increased gas content in the separately ventilated part of the face. This system is recommended in systems with low methane content, with blind part of the longwall face up to 10 m [5].

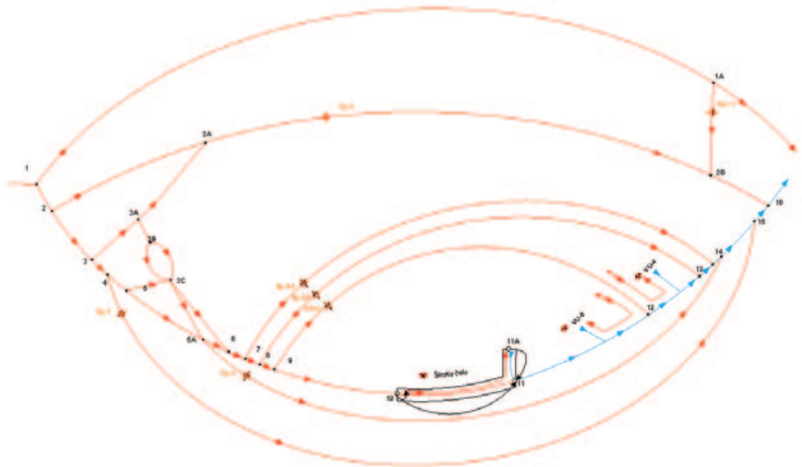

Figure 7. Cannonical ventiilation scheme – ventilation regime «C» [5]

4. MAIN PROPERTIES OF THE MODEL FOR SOLUTION TO THE ENCOUNTERED PROBLEMS IN THE LONGWALL MINING

Results of the recorded ventilation parameters and longwall face advance obtained in the 5 years period, in which three panels were mined out, and of regular chemical analyses of the mine air in that period, were basis for the one factor and two factor regression analyses of parameteres influenci$_{n}$g gasses$_{s}$ ocurrences (qCH_4 and qCO_2) and of fires (apsolute inflow of CO) for the all applied ventilation regimes [6]. Independent variables that were included are as follows: air quantity (V), advance rate of longwall face (n) and alterations in barometric pressure (B).

It was observed that relations between observed occurences drastically change with alterations in ventilation regime at longwall face. Gassess ocurrences increase in all regimes applied with drop in barometric pressurre (B). It was connected to (n) and (V) as well, but with significant differences in each of the applied ventilation systems.

Occurences of spontaneous fires are more related to applied ventilation systems, and depend on changes in air quantity (V), longwall face advance rate (n) and barometric pressure (B),

Two-factor regression analysis of gasses ocurences: $qCH_4 = f\ (n, V)$; a for $qCO_2 = f\ (n, V)$, points to a very solid connection at „A" ventilation regime, whereas that connection is weak at „B" and „C" ventilation systems.

Two-factor regression analysis determined a high influence of (V) and (n) parameters on fire occurences at „A" ventilation regime, whereas that connection between the parameters is weak at „B" and „C" ventilation systems.

Results of conducted analyses, practical observations of mentioned hazards, and some other hazards too (rock burst occurences and hazardous mine dust), gave a basic quidelines for model development (ventilation system) to be used for minimisation and elimination of certain hazards, that has to fullfill the following conditions:

- mining has to be carried out without safety pillars
- to preserve positive balance of gasses CH_4 and CO_2,
- mining without open contacts of ventilation ways with gob of the overlying panel,
- number of rooms in the endagered upper part of the panel to be reduced to minimum, to minimise rock burst occurences risk.

Giving the fact that requirements for the model development are quite variable, then solutions have to be sought that fulfill all set conditions to the most possible extent. Instead of safety pillar toward the gob, to avoid direct contact of active ventilation ways with gob of the overlying panel, a temporary safety pillar has to be left.

This pillar is projected to allow connection of the gobs of the working panels, immediately upon passage of the working face. Thus the function of this pillar in the first phase is to prevent open contact of actively ventilated rooms with the gob of the overlying panel, and upon passage of working face it collapses, connect the gobs and enable exchange of gases, CH_4 and CO_2. Thus the fire and rock burst occurrences are reduced and gasses exchange enabled, To secure the model to be fully successfull it is neccessary to explore system of development workings that will secure normal advance of development workings, and simultaneoulsy reduce the number of rooms in the endagered part of the mining panel.

5. PROPOSED LOCATION OF THE VENTILATION HALLWAY (LONGWALL FACE VENTILATION REGIME)

Taking into account the adopted experience based principles for the analysed case, and all influential factors, the most acceptable ventilation regime proved to be:

Mechanised longwall mining of the roof plate with ventilation and middle hallway (isolation safety pillar left toward the gob of the overlying panel, without the open contact toward the gob).

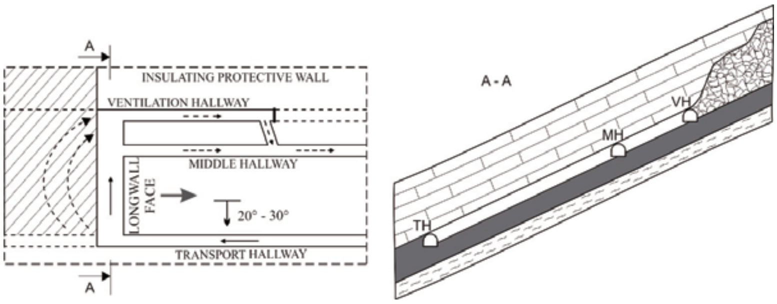

Figure 8. Longwall mining of the roof plate with ventilation and middle hallway-with isolatio safety pillar toward the gob of the overlying panel, without open contact with the gob

Proposed ventilation regime secures: exchange of gasses, ventilation without the contact of active workings with the gob of the overlying panel, reduced time required for construction of ventilation incline, and mining without safety pillar. This model reduces spontaneous mine fire and hazardous gassess occurences, and minimises the risk of rock bursts. Development operation include drivage of ventilation (later middle) hallway to secure special ventilation units during development and mining operations. Distance between ventilation-middle hallway and the gob, was altered during the mining operations in panel, therefore it is required to reconsider distance between ventilation hallway and the gob based on collected geomechanical data. Number of short connecting ventilation inclines would be reduced considerably, since they can be driven on distance of every 300-500 m. Number of rooms would be reduced significantly in the parts endagered with rock bursts. Isolation safety wall toward the gob would be set in accordance with longwall face advance. Timely and quality construction of the isolation wall would reduce inflow of air through the gob of the working panel. Thus the occurences of mine fires and gasses release (from the gob) would be reduced in the working panel. The wall would be used not only for isolation but for bearing purposes as well, in order to secure better preservation of the gas channel during the mining phase.

6. CONCLUSION

Research and analysis of endogenous fire and gasses release at mechanised longwall mining of the main seam roof plate in „Raspotočje" mine, operation of „Zenica" brown coal mines, was based on mining experiences, and analyses of a large number of gathered ventilation, mining and other parameters. Data analyses are performed using regression analysis method , and contemporary computer programs that enable fast and efficient check up and research into correlation of parameters [6].

Gained practical mining experience indicated a number of shortcomings of the applied mining system, that coupled with unfavourable natural conditions resulted in mining bearing high level of risks. Beside two methane inflammation, mining was followed by a frequent spontaneous fire and rock burst occurences, ranging from low to high intensity [10].

Test results and practical knowledge in mining of the analysed working panels, lead to the following conclusions:

1. Mining in the working panels in given conditions (high methane content in coal and accompaning seams with high free methane accumulations) has to be preceeded by one of the degassing activities

[3] [4], or to start with mining phase half the year upon completion of development operations (to secure time required for the partial degassing of the working panel).
2. Mining in the working panels has to be performed without safety pillars, to reduce risks of rock burst occurences, to secure exchange of gasses (CH_4 and CO_2), and to maintain the CH_4 concetration within the permitted limit [5] [9].
3. Development operations in the working panels has to be brought into conformity with advance rate of the active working panels. Alteration in geological conditions in the block (microtectonics) and strong outbursts of accumulated free methane, can significantly slow down or completely disable normal execution of the development operations.
4. Number of rooms driven in the panel has to be reduced to minimum, and the position of hallways by the gob has to be carefully determined (location of the ventilation-middle hallway and short connecting inclines.
5. Development of the auxilliary rooms underneath the transport hallway (in the area of the next panel) during the mining in the working panel has to be reduced to minimum, and these rooms has to be sealed when longwall face approaches . Experience and analyses based results indicate that the most frequent occurences of spontaneous fires are connected with these rooms (sumps, temporary sumps, storage chambers, etc)
6. Accompaning systems (transport, dewatering, material sypply delivery) have to be brought in conformity with the applied mining method to reduce influences of natural hazards.

Possibility of complete one web mining of the main coal seam is to be explored. Coal seam – floor section as oppose to coal seam – roof section, has low propensity to rock bursts, therefore driving the opening hallways in the floor plate and transfering the longwall equipment into the floor plate would reduce rock bursts occurrence risk significantly [9].

REFERENCE

[1] Adilović A. ,Marković, J., Gutić.K. (2006): Uticaj ekvivalentnog otvora širokog čela na pojavu požara, Međunarodni rudarski simpozijum: Istraživanja, eksploatacija i prerada čvrstih mineralnih sirovina, Dubrovnik 8-10.11.2006., R Hrvatska.
[2] Adilović A., Adilović N., Karadžin Z. (2016): Potencijalne opasnosti u podzemnim rudnicima, OFF-SET Tuzla.
[3] C. Őzgen Karacan: Degasification system selection for US longwall mines using an expert classification system. National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Pittsburgh, PA 15236, USA, URL: https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/dssfu.pdf
[4] Kozłowski B., Grębski Z. (1982): Odmetanowanie górotworu w kopalniach, Wyd. Śląsk, Katowice.
[5] Kurbašić R. (2019): Grafoanalitička metoda analize kompleksa aktivnih i pasivnih mjera zaštite od podzemnih rudničkih požara, doktorska disertacija, RGGF Tuzla.
[6] Kurbašić R. (2004): Položaj ventilacionog hodnika kod širokočelnog otkopavanja u funkciji gasne i požarne opasnosti, Magistarski rad, RGGF Tuzla.
[7] Marković J., Mićević S. (2005): Požari u rudnicima uglja, RGGF Tuzla.
[8] Marković J., Tanović H., Mičević S. (1997): Release of methane as a function of longwall face advence rate, 27. International conference of safety in mines research institutes, New Delhi (India), 20-22 Feb 1997.
[9] Sakić E. (2003): Iskustva i inovacije u prevenciji zaštite od gorskih udara pri otkopavanju u jami Raspotočje, Magistarski rad, RGGF Tuzla.
[10] Technical documentation of Zenica Brown Coal Mines.