VENTILATION SYSTEMS IN LONGWALL WORKINGS WITH A POWERED LONGWALL COMPLEX

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ABSTRACT

One of the main problems when carrying out underground mining is to ensure an adequate amount of fresh air in mining excavations. In particular, this applies to longwall workings with powered longwall complexes. These high-performance machine sets enable fast and efficient mining of the rock mass along with the transport of output outside the face zone. The factor affecting their efficiency and effectiveness is adequate ventilation of excavations. The article presents the analysis of ventilation methods of longwall excavations in hard coal mines in Poland and modern systems of registration and monitoring of ventilation parameters in longwall excavations. These solutions require the use of advanced IT and telecommunications solutions. It conforms to the ideas of industry 4.0, which is increasingly used in mining. The practical application of cyber-physical systems can significantly improve the safety and efficiency of mining operations. The example presented in the paper concerns a new longwall excavation, prepared for operation. The use of digital recording and data transmission systems enables the current diagnosis of the methane hazard. The presented concept and research results should improve the efficiency of the entire mining process.

Keywords: *methane hazard, ventilation, industry 4.0, mining*

INTRODUCTION

Underground hard coal mining is increasingly applying high-efficiency longwall systems. They consist of a mining machine, a longwall conveyor and a powered roof support). The mining process is related to various types of natural and technical hazards, due to its intensity and operation of deeper layers. In order to ensure the continuity of the operation process and its safety, it is necessary to properly recognize and project these hazards. This requires the use of modern techniques, technologies, devices and machines, as well as appropriate knowledge about phenomena that are linked with the mining exploitation process is required. One of the most dangerous hazards related to the mining process is methane hazard [3], [8], [9]. Methane content in coal seams greatly impacts the safety of people and machines. This hazard arises as a result of the release of methane during the mining process. Determining the methane content in coal seams is an important step to assess the methane hazard in the seam. This particularly refers to new seams. In the last 10 years (2009-2018) there have been 8 tragic events around the world caused by methane. As a result, 541 miners were killed. Three hundred and one people were killed in an accident in Turkey in 2014, which is the event in the mine caused by methane that resulted in the highest number of deaths. Other accidents with high number of deaths took place in Poland in 2009, 20 miners, an, in Russia in 2010, 66 victims. In the same year in the United States 29 miners were killed [12]. It can be concluded that methane is a highly dangerous gas and constitutes a real threat to mining operations.

The mines with the highest methane level in 2016 in Poland were KWK Budryk (146 million m^3 CH_4) and Pniówek (103.96 million m^3 CH_4) [5]. The amount of methane emitted in hard coal mining is high due to the increasing depth of exploitation, higher methane content of deeper seams, the occurrence of a "pocket" of methane trapped under pressure in the zones of tectonic disturbances and high concentration of extraction.

The article presents a new approach to ventilation of longwall excavations. Currently applied methods of ventilating a longwall excavation are discussed including their advantages and disadvantages. An example of determination of ventilation parameters for a newly designed longwall in the conditions of a high methane hazard in the mine of Polska Grupa Górnicza SA was also presented. The article should be treated as an introduction to the analysis of the effectiveness of ventilation of underground excavations.

CHARACTERISTIC OF APPLIED VENTILATION SYSTEMS

The factor significantly impacting the safety of persons working in underground coal mines is the effective ventilation of these excavations. The main purpose of ventilation of excavations is to provide fresh air to the crew and reduce the gas hazard associated with the operation. Among natural hazards, the most important from the point of view of ventilation safety are methane and fire hazards [1], [2], [3], [10]. The methane hazard and the fire hazard are examples of associated hazards, strongly related to each other. When selecting the method of ventilation in the longwall, mining ventilation services have to often select the be safer and more effective system in the case of the co-occurrence of both these hazards. Generally, the ventilation method, which is better suited to eliminate methane hazard, is less beneficial if there is a fire hazard. This problem occurs mainly in the case of a goaf, a highly porous medium, subject to both types of hazard [1], [2], [6], [10].

Ventilation of longwall workings is aimed at distributing air in the walls in such a way as to limit the flow of methane to excavations, increase the temperature and effectively dilute the gases and dust that occur there. The extraction longwalls are ventilated using various methods, including longwall walkways [7], [11]. The most frequently used methods of ventilation are the U, Y and Z methods as well as the H method which requires maintaining longwall walkways. There are two types of methods to carry out the ventilation. The first one runs starting from the borders of the field of exploitation. The second one runs towards the borders. The U method of ventilation of the exploitation longwall is shown in Figure 1a.

The air in the U system is supplied and discharged from the longwall through main gates. It is in contact with goafs along their entire length, hence it is necessary to seal them. The main advantage of this method is the possibility of simultaneous carrying out preparatory works and coal exploitation. This method has a positive effect on the mining process carried in the areas where the rock burst hazard occurs. In the case of high intensity of air flow through the goafs, the fire hazard increases, which is a fundamental disadvantage of this method of ventilating. This system is not recommended when level of methane in the longwall is very high, with a relatively high-temperature increase and because of the danger of spontaneous ignition of coal in the caving.

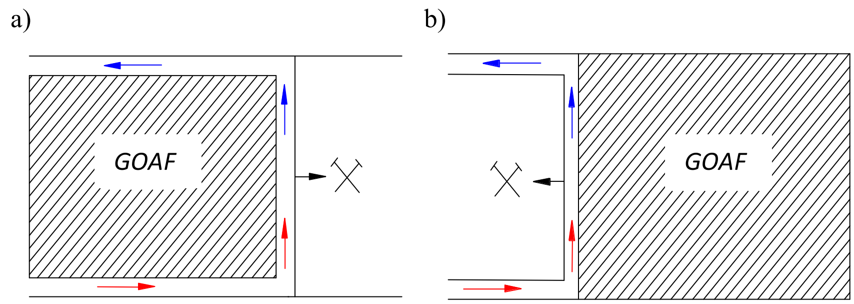


Fig. 1. Schemes of U ventilation systems that reach the borders of the field of operation (a) and applied starting from the borders (b)

In the U ventilation system applied starting from the field borders (Fig. 1b), the air is supplied through the bottom gate and transported away through the top gate. This method of ventilation of the longwalls has two basic advantages, namely, there is a limited airflow through the goafs, and as a result, a limited fire risk in the goafs. The advantage of this method is also the ability to recognize changes in the methane content of the seam. Disadvantages of this method of longwall ventilation include elevation of methane and thus an increase of methane hazard at the outlet from the longwall and the necessity of using additional ventilation devices at the intersection of the longwall −ventilation gate [1], [2], [3], [4]. The disadvantage of this ventilation system is also the supply of heat to the wall of goafs.

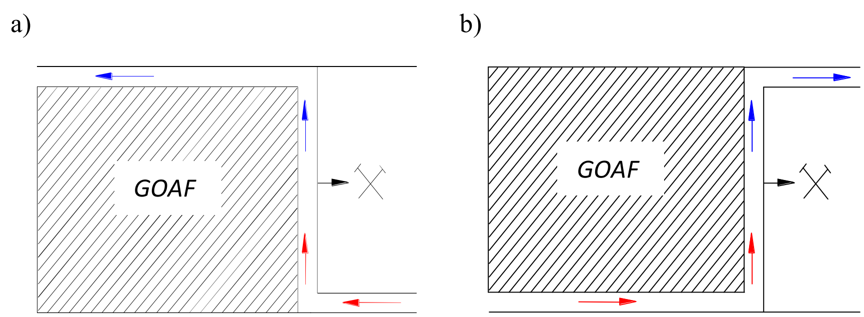


Fig. 2. Schemes of U ventilation systems and applied starting from the borders (a) and that reach the borders of the field of operation (b)

In the Z ventilation system running from the field boundaries (Fig. 2a), the air flowing through the extracted longwall is in contact along its entire length with the goafs and top gate adjacent to the goafs. The air stream with methane does not accumulate in the longwall, because it only flows out in the top gate, which results in a smaller methane hazard in the longwall. The main drawback of this method of ventilation is the possibility of free flow of air through the goaf for a long period of time which increases the fire hazard in the goaf and leads to an endogenous fire.

In the Z system reaching the borders (Fig. 2b), the air stream supplied to the longwall through the bottom gate also influences the goaf and elutes the accumulated methane. It causes that the mixture of gases flowing through the longwall creates a serious methane hazard in the upper section of the longwall. The temperature of air flowing through the goafs can be very high thus creating unfavorable climatic conditions in the longwall. The air migrating to goafs also may lead to fire. This system is not beneficial in case of any ventilation hazards.

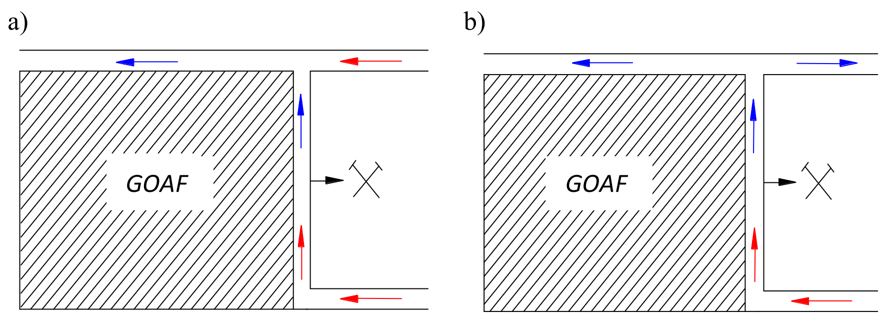


Fig. 3. Schemes of Y ventilation systems with reblowing through the top gate (a) and with the air discharge in two directions (b)

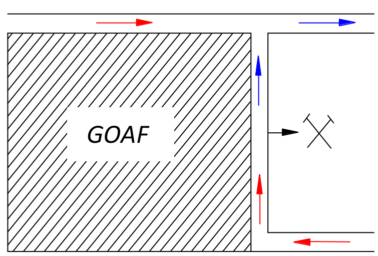
In the Y system with reblowing through the top gate (Fig. 3), the air stream is supplied through the bottom gate to the longwall, and additionally through the fail gate (reblowing). The used air is discharged from the longwall through the top gate (along the goafs). This method for ventilation is used in the areas where methane outflows from goafs is substantial. The methane transported from them to the top gate is diluted with more air. Such a system is advantageous because it limits the methane hazard as it moves away the zone of dangerous concentrations of methane in the goaf from the working areas. In contrast, the disadvantage of the above system is the possibility of air flow through the goafs, which may increase the self-heating of coal in the goaf, thus increasing the fire hazard. In order to limit the volume of air escaping through the goafs, it is necessary to seal off the sidewalls of longwalls located near the goafs.

The variant of the Y system with reblowing through the top gate is used in low-thickness seams, when the air cannot flow through the longwall in the amount adequate to the existing methane.

There are two types of the Y system, long and short. The long Y system is applied when there are no issues with maintaining proper dimension of the excavation following the longwall. The second type, the short Y system, is used when maintaining the dimension of the excavation located behind the caving of the longwall is not possible. This gallery is maintained only on such a section, on which it is possible to maintain proper dimensions.

In the Y ventilation system with air extraction in two directions (Fig. 3b), the air flow is supplied to the longwall through the bottom gate and carried away in two directions through the top gate. In the section of the top gate, the air does not come into contact with the goafs and there are no high concentrations of methane, because it is partially discharged from the goaf along with the used air through the top gate maintained along the goafs. This method is preferred when operating in conditions of rock burst hazard. The disadvantage of this method of ventilation is the increased fire hazard in the goaf and the necessity of sealing the main gate sidewalls. This system combines the advantages of U and Z systems, simultaneously eliminating some of their disadvantages. This system is used at high walls, because the whole air must flow through the longwall. The large amount of air and its high speed also have a positive effect on climatic conditions and air pollination with the respirable fraction.

a)



b)

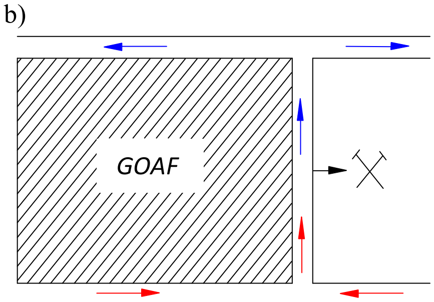


Fig. 4. Layout of the Y ventilation system with reblowing through the top gate starting from the goafs and using the H system.

In the Y system with reblowing through the top gate (Fig. 4a), the air stream is supplied through the bottom gate to the longwall, and additionally through the top gate (reblowing) maintained along the goafs. In this case, it is necessary to seal it. The used air is discharged from the longwall through a top gate. Ventilation of longwalls in this way increases the methane hazard in its corner and contributes to the inflow of heat to the longwall from goafs. This ventilation system is preferred in the case of a fire hazard, because it is possible to supply neutral substances to goafs. The system can be used in low longwalls with medium methane level.

The H ventilation system (fig. 4b) requires maintaining longwall main gates located near the goafs. Fresh air is supplied to the longwall through the bottom gate (also maintained from the side of the goaf), and it is discharged from the longwall through the top gate (including towards the goaf). This method is characterized by a strong ventilation of the goafs, it is therefore beneficial for use in the case of rockburst hazard, methane and climatic hazard. However, the use of this method is disadvantageous due to possible endogenous fire in the goaf.

OPTIMAL VENTILATION MODEL

To determine the optimal method of ventilation, it is necessary to analyze the natural hazards and the expected geological disturbances resulting from the mining activities carried out so far. Based on the methane level projections, the amount of methane to be extracted during mining is anticipated, taking into account the progress rate and methane level in the goafs. In such cases, forecasts of the methane hazard condition are also carried out [4].

The chapter presents an example of determining ventilation parameters and the route of supplying fresh air to a longwall working. The subject longwall area is presented in Figure 6.

In the analyzed case, the methane content ranges from 31.26 m^3/min for the extraction of 2000 Mg/day to 35.36 m^3/min for the production of 2400 Mg/day. The tested seam 408/1 in the IIIz area was classified as the third category of methane hazard. Due to the methane hazard, the amount of air that should be supplied to the longwall depending on the progress of this longwall was assumed. The following daily wall progress was assumed for calculations: 1.87 m, 2.49 m, 2.81 m, 3.12 m, which are supposed to correspond to the actual values of the daily production. The longwall will be operated at a depth of around 600 ÷ 620 m. The calculations include the amount of air supplied to the longwall through the gate and auxiliary lute. The amount of necessary air was calculated from the following dependence:

$$Q_m = \frac{K \times q_m(100-E)}{n_2-n_1}[m^3/min] \quad (1)$$

where:

K − factor taking into account the peak evolution of CH_4 = 1.55,

n_2 − permissible methane concentration in the outlet airflow - 2.0% (from the area of 1.5%),

n_1 − methane concentration in the inlet airflow, 0.0%,

E − efficiency of demethanization - 55%,

q_m − predicted methane content, corresponding to the adopted quantities of progress and extraction, based on measurements and tests.

Calculated for individual assumed sizes of progress and the corresponding extraction quantities, the minimum amounts of Qm air carried away from the longwall due to extraction and gas content of the deposit are:

− for extraction of 1,200Mg/day: Q_m = 773 (573 + 200) m^3/min,

− for extraction of 1,600Mg/day: Q_m = 938 (738 + 200) m^3/min,

− for extraction of 1,800Mg/day: Q_m = 1016 (816 + 200) m^3/min,

− for extraction of 2,000Mg/day: Q_m = 1090 (890 + 200) m^3/min,

− for extraction of 2,400Mg/day: Q_m = 1234 (1034+200) m^3/min,

− for extraction of 2,400Mg/day: Q_m = 1234 (934 + 300) m^3/min,

Figure 5 presents a scheme of ventilation of an exploitation longwall equipped with a powered roof support.

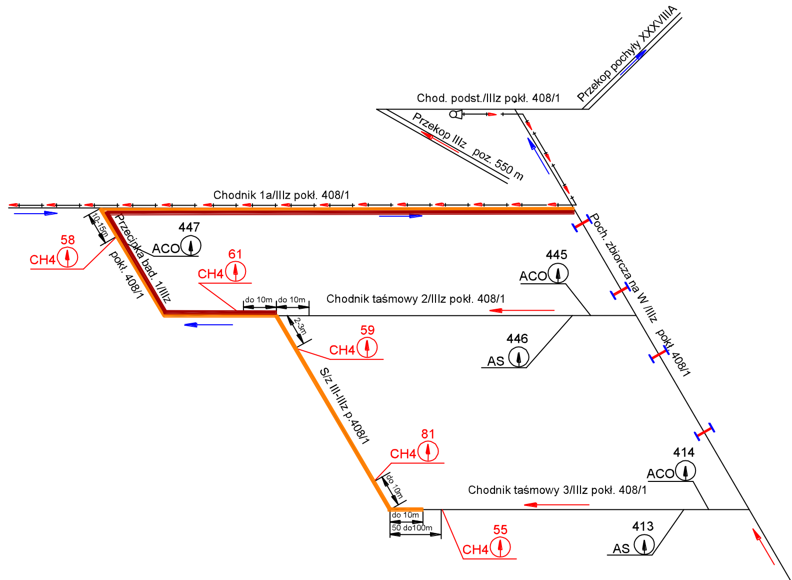


Fig. 5. Adopted ventilation system for the designed longwall complex

CONCLUSION

Continuous mining of coal in an underground mine requires actions aimed at limiting and preventing natural hazards. The increasing depth of exploitation is a factor influencing the increase of methane hazard. In order to ensure the appropriate conditions of ventilation in the longwall, there is often the need to use new methods to limit the methane hazard. On the basis of projected methane hazard and air demand for an exemplary longwall with different extraction volumes, the required airflow was determined. The determined efficiency of this airflow should ensure effective ventilation of the mining area. When determining the size of the airflow, the depth of exploitation was also taken into account.

The obtained results and the authors' experience indicate that in the further stages of the conducted operation it is necessary to check the determined values and modify them. Some ventilation parameters may change during operation, and then the whole system may be disturbed. There is no doubt that an effective ventilation system in coal mines is the basis for efficient and safe operation.

The authors of the article believe that their work on the efficiency of ventilation of longwall workings will contribute to the improvement of work safety.

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