PRZEGLĄD GÓRNICZY
założono 01.10.1903 r.
MIESIĘCZNIK STOWARZYSZENIA INŻYNIERÓW I TECHNIKÓW GÓRNICTWA
Nr 9 (1137) wrzesień 2017 Tom 73 (LXXIII)

Danger zone of spontaneous combustion in the gob with lower entry retained along the gob

Strefa zagrożenia spontanicznym spalaniem w zrobach z podścianowym chodnikiem utrzymywanym wzdłuż zrobów

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Abstract: In recent years, with the increase in mining depth and the change of mining methods (such as: mining with entry retained along the gob, using Y- type ventilation system), the risk of spontaneous combustion has increased, threatening the safety in coal mine. In order to determine the danger zone of spontaneous combustion in the gob, so as to provide the basis for fire prevention, temperature probes and gas exhausting pipes were embedded in the gob along the upper entry and behind supports. Temperature and oxygen concentration at different sites were obtained. Based on the rate of temperature rise and oxygen concentration changes, the risk zone of spontaneous combustion and the features of the "three zones" in the gob were obtained. The heat dissipation zone is very narrow, the widest position of the heat dissipation zone and the oxidation zone are in the triangle strip formed by hydraulic supports and the wall of gangue bags along the lower entry retained along the gob.

Treść: W ostatnich latach, wraz ze wzrostem głębokości oraz zmianą sposobów wybierania pokładów węgla (np. wybieranie z chodnikiem przyścianowym utrzymywanym wzdłuż zrobów, używanie systemu wentylacji ścianowej typu Y), zwiększone ryzyko samozapłonu zagraża bezpieczeństwu w kopalniach węgla kamiennego. W celu określenia strefy zagrożenia spontanicznym spalaniem w zrobach i zapewnieniu podstaw zapobiegania pożarom, osadzono sondy temperatury i czujniki tlenu w zrobach wzdłuż chodnika nadścianowego, za obudową zmechanizowaną. Następnie przebadano temperaturę oraz stężenie tlenu w różnych miejscach pomiaru. Na podstawie tempa wzrostu temperatury i zmian stężenia tlenu wyznaczono strefę zagrożenia samozapaleniem. W ten sposób wyznaczono «trzy strefy» w zrobach. Strefę rozpraszania ciepła, która jest bardzo wąska, szersze są strefy rozpraszania ciepła i utleniania, które znajdują się w trójkącie utworzonym przez obudowy hydrauliczne i ścianę.

Key words:
mine fires, spontaneous combustion, fires in gob
Słowa kluczowe:
pożary podziemne, spontaniczne spalanie, pożary w zrobach

Introduction

CT101 of Wugou Coal Mine is a fully mechanized longwall. The goaf is filled with gangue. Along the gob side the lower entry is retained by constructing a piled wall of trapezoidal gangue bags. The retained entry is ventilated by a local fan with positive pressure.

Retaining an entry along the gob without pillars is a mining technology with improved recovery rate and reduced excavation works to ensure continued and improved efficiency and to reduce costs of mining. But there are some problems that cannot be ignored. Because the problem of air leakage into the gob is difficult to resolve, spontaneous combustion often occurs in the gob, in the open cut, and upper and lower entries. For this reason, spontaneous combustion prevention is very important.

Due to the impact of ventilation in the retained entry along the gob, airflow in the gob is more complex than in the gob of a longwall with "U" type ventilation. Air leakage in the gob filled with gangue is different to air leakage in the gob with roof caving. Distribution of the "three zones" in the gob is also different.

"Three zones" distribution is a key parameter for spontaneous combustion prevention. In order to understand the "three zones" in the gob of longwall CT101 of Wugou Coal Mine under conditions of mining with fill and retaining the gob-side entry to assist with fire prevention in the gob, the "three zones" distribution in the gob was studied.

1. The methods of spontaneous combustion risk determination in the gob

As a high-risk area of spontaneous combustion of coal, the gob is the key area for spontaneous combustion prevention. The premise of spontaneous combustion control in gob is to find out the distribution range of spontaneous combus-

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tion “three zones” in gob, which is the main basis for the technical measures of spontaneous combustion control in gob. Therefore, the study of the distribution of spontaneous combustion “three zones” in gob is one of the main basic research contents of fire prevention work.

Spontaneous combustion “three zones” mainly refers to the heat dissipation zone, oxidation zone and the asphyxiation zone. In the heat dissipation zone the air leakage speed is larger, and the heat generated by coal oxidation in the gob cannot be accumulated, and the spontaneous combustion does not occur normally. In oxidation zone the air leakage speed is appropriate, and the conditions of heat accumulation are good and oxygen supply meets the coal oxidation needs, so in the zone the risk of spontaneous combustion is high. In asphyxiation zone due to small air leakage, volume concentration of oxygen is difficult to meet the needs of oxidation, generally spontaneous combustion does not occur.

At present, there are three kinds of the “three zones” determination methods in the gob:

– According to the air leakage speed in the gob. This method is mainly by laboratory model experiment to simulate with the actual conditions on the mining site. The actual measurement on the site is difficult to be conducted due to the difficulties of access to the gob, the insufficient accuracy of the measuring instrument, and the unpredictability of the air leakage direction in the gob and so on. According to the study of domestic and foreign scholars on the air leakage in the gob, it is concluded that the "three zones" in the gob are divided according to the speed of air leakage in the gob (Yang et al 1998): the airflow speed in the heat dissipation zone is greater than 0.24 m / min; airflow speed in the oxidation zone is 0.24 to 0.1 m / min; in the asphyxiation zone airflow speed is less than 0.1m / min.
– According to the oxygen concentration. This method is commonly used in field measurements, according to the oxygen concentration “three zones” are generally divided as the following: in heat dissipation zone oxygen concentration is greater than 15% ~ 18%; in the oxidation zone oxygen concentration is 5% to 15%; in the asphyxiation zone oxygen concentration is less than 5% (Liu et al 2009).

In the gob, even if the leaking air flow forms the condition for the oxidation of coal, the temperature in the gob does not rise if a factor can limit the heat accumulation in the gob, so that spontaneous combustion does not occur. In the oxidation zone determined according to oxygen concentration or the air leakage speed the appropriate conditions of heat accumulation do not necessarily occur. Therefore, determination of spontaneous combustion risk zone according to the oxygen concentration or the air leakage speed has some limitations.

– According to the rate of temperature rise. If the daily increase of temperature in the gob is greater than 1 °C/ d, the area is considered as the oxidation zone (Xie, Xue 2011, Jiang et al 1998). In the oxidation zone the conditions and possibility of spontaneous combustion exist. However, if the temperature in the gob does not rise one cannot say the “three zones” do not exist. In addition, the asphyxiation zone may be formed by oxygen consumption in oxidation, or may be formed due to a large amount of inert gas emission, and the temperature in the latter situation may not significantly increase. Therefore, it can be used as an auxiliary indicator when the conditions are appropriate.

In summary, the “three zones” should be determined by use of oxygen concentration at the same time taking into account the temperature field distribution, temperature changes and the gas concentration changes in the gob. Oxygen concentration is used as the main index and the temperature as the auxiliary index to divide the “three zones”, that is, when oxygen concentration index is used to divide the “three zones” in the gob, taking account the temperature field distribution and temperature change, as well as changes of other gas concentrations in the gob.

2. Overview of longwall CT101

Longwall CT101 is the Wugou Coal Mine’s first fully mechanized longwall with the gob filled with gangue. The thickness of coal seam no. 10 is 2.2 ~ 3.9 m, with an average thickness of 3.1 m. The spontaneous combustion tendency of the coal seam belongs to class II. The lower entry is retained along the gob by constructing a wall of trapezoidal gangue bags (width at the top 2 m, width at the bottom 3 m), additional support along another side of the entry is with a cable and steel beams.

The longwall coal seam is mined by double-drum electric traction shearer. The average mining height is 3.1 m, cutting depth 0.6 m. The mining operation is followed by backfilling the gob cyclically after one cut, the filling step is 0.6 m.

The lower entry retained along the gob is pressurized by local fans. The local fan is located at 85 m from the crossing point of CT101 lower entry and CT101 connecting airway for ventilation. The rated capacity of the local fan is 3.0 ~ 4.4 m^3/s (178 ~ 266 m^3/min), the maximum air flow is 4.4 m^3/s (266 m^3/min) and the fan pressure is 400 ~ 3155 Pa. The ventilation duct is selected with a diameter of 500 mm, with flame retardant and antistatic properties (Yuan, 2012).

3. “Three zones” observation in the gob CT101

The observation system and measuring points in the gob CT101 were determined from the point of view of reliability, convenience, economic realization and other considerations, the scheme is shown in Figure 1.

The tube-bundle system for gas sampling and the thermocouple system for temperature measurement are arranged in the upper entry, and the systems are protected with a steel pipe, the probes are protected with a steel tee pipe as shown in Figure 2. Three measuring points are arranged with a spacing of 18 m.

The thermocouple system for temperature measurement is arranged in the gob behind the hydraulic supports, the thermocouple system is protected with a PVC pipe, and the probes protected with a steel pipe, as shown in Figure 3.

Four temperature measuring points are arranged behind the hydraulic supports, height of the measuring point location from the floor is 2 m, and the distance of the measuring points from the gob side at the lower entry is respectively 7 m, 28 m, 55 m, and 67 m.

The straight distance of the measuring line in the gob behind the hydraulic supports from the observation station in the upper entry is 100 m. Measuring point 7 in the upper entry is located 100 m from the observation station in the upper entry.

During the construction process the thermocouple cables are dragged behind the hydraulic supports. The measuring points are dragged in order as thermocouple cable of measuring point 4, thermocouple cable of measuring point 3, thermocouple cable of measuring point 2, thermocouple cable of measuring point 1. Measuring points 5, 6 and 7 are arranged in the upper entry and protected with steel pipe.

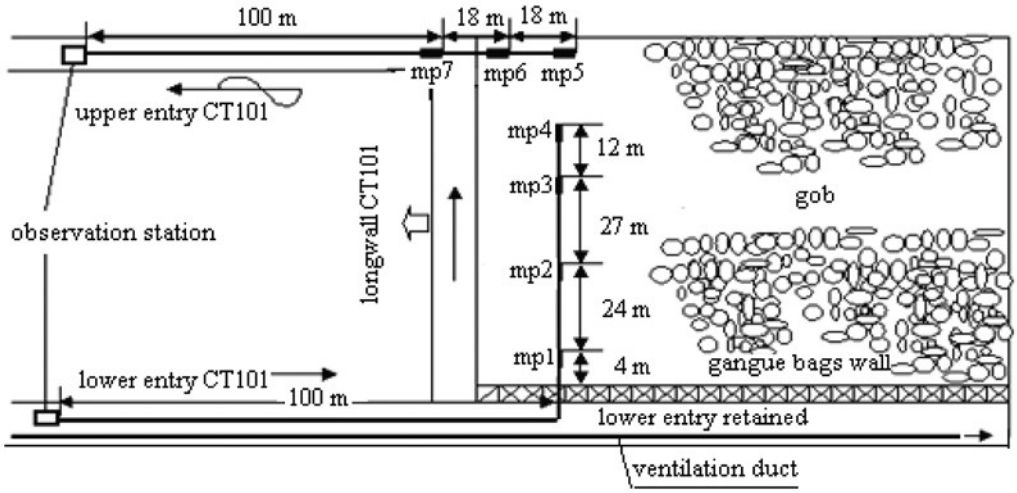

Fig. 1. The observation system and measuring points
Rys. 1. System obserwacji i punkty pomiarowe

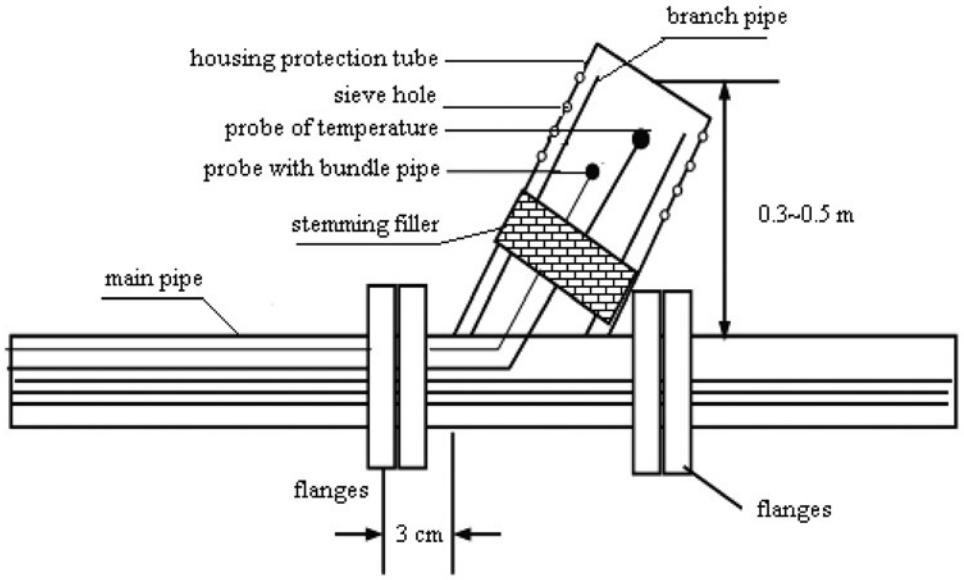

Fig. 2. Scheme of probe at measuring points 5, 6 and 7
Rys. 2. Schemat sondy w punktach pomiarowych 5, 6 i 7

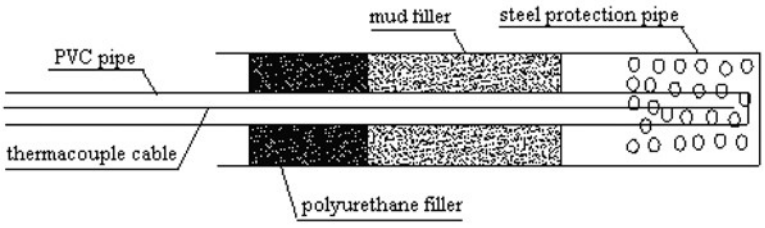

Fig. 3. Scheme of the probe at measuring points 1,2,3,4
Rys. 3. Schemat budowy sondy w punktach pomiarowych 1,2,3,4

4. The results of observation in the gob and data processing

After arrangement of measuring points No. 1 to No. 4, measurements are taken once every 2 to 3 days. When measuring, point No. 5 is buried in the gob, an observation is taken once every 2 to 3 days. The relationship between temperature measured at measuring point No. 1 to No. 5 and the depth of the measuring points buried in the gob is shown in Figure 4. and Figure 5. The relationship between oxygen concentration at measuring point No. 5 and the depth of the measuring point buried in the gob is shown in Figure 6.

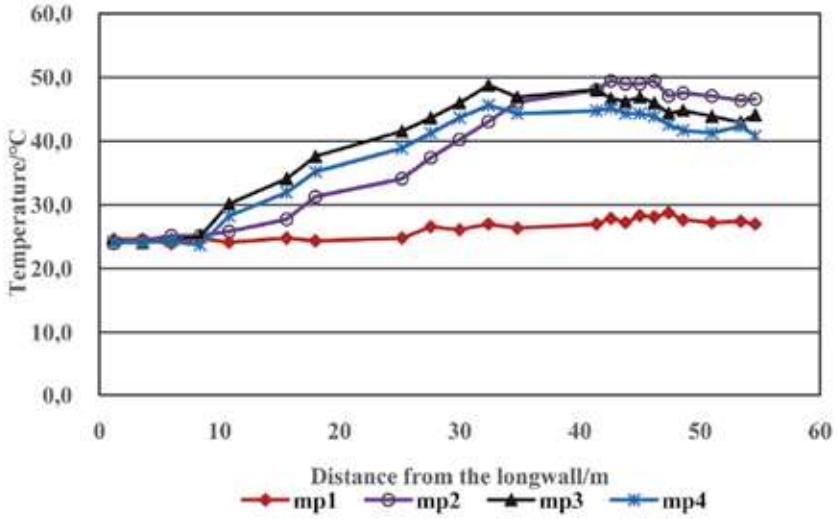

Fig. 4. Temperature change with depth at mp 1~mp4
Rys. 4. Zmiana temperatury od odleglości w punktach pomiarowych mp1 ~ mp4

According to the trend of temperature and oxygen concentration changes at the measuring points, based on the criteria for "three zones" determination, distribution of the "three zones" in the gob CT101 is obtained as shown in Figure 7.

As the longwall is mined with the gob being backfilled, the "three zones" in the gob changed rapidly. According to the criteria for "three zones" determination, the regularity of the "three zones" distribution can be drawn as the following: the starting position of the heat dissipation zone is 0 ~ 10 m from the longwall, the starting position of the oxidation zone, which is danger zone of spontaneous combustion is 10 ~ 45 m from the longwall and the starting position of the asphyxiation zone is farther than 45 m from the longwall. From a safety point of view, for the width of the heat dissipation zone the smaller value should be chosen, and the range of the oxidation zone should be extended forward or backward to some extent.

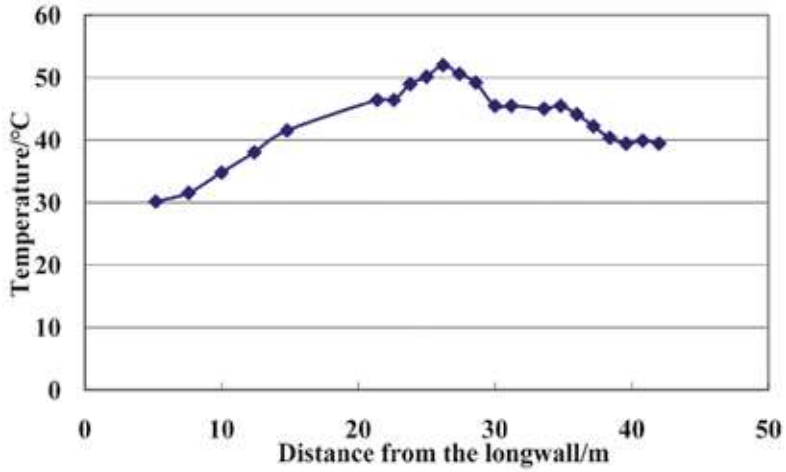

Fig. 5. Temperature change with distance at mp 5
Rys. 5. Zmiana temperatury od odległości w punkcie pomiarowym 5

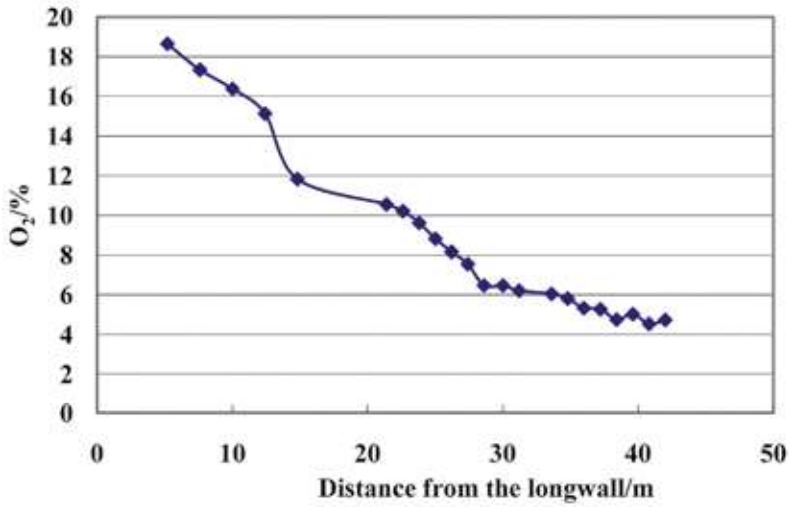

Fig. 6. Oxygen concentration change with distance at measuring point 5
Rys. 6. Zmiana stężenia tlenu od odelgłości w punkcie pomiarowym mp5

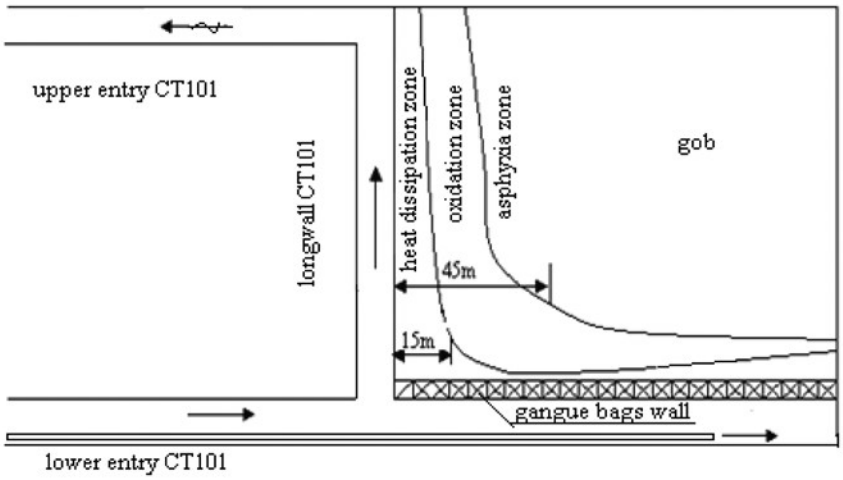

Fig. 7. Distribution of "three zones" in the gob
Rys. 7. Rozkład «trzech stref» w zrobach

5. Conclusions

The starting position of the heat dissipation zone is 0 ~ 10 m from the longwall, the starting position of the oxidation zone is 10 ~ 45 m from the longwall and the starting position of the asphyxiation zone is farther than 45 m from the longwall. A heat dissipation zone with width of about 7 m exists in the gob near the inside wall of gangue bags, indicating that a continuing strip of air leakage occurs along the wall of gangue bags.

Under conditions of mining with the gob backfilled with gangue, the distribution of "three zones" is quite different compared with mining under conditions of roof caving in the gob. Transition of the heat dissipation zone into the oxidation zone is fast. Width of the heat dissipation zone and the oxidation zone is relatively smaller than in the gob with roof caving. The "three zones" distribution can be roughly represented as strips.

The lower entry retained along the gob is ventilated by forced ventilation resulting in significant air leakage. A wide area of the oxidation triangle zone in the gob exists along the gob-side wall of the lower retained entry. As the air leakage conditions are good for coal oxidation, the area should be a key location for fire prevention.

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Artykuł wpłynął do redakcji – czerwiec 2017
Artykuł akceptowano do druku 7.08.2017