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Theoretical analysis and applications of Y-Inversion Ventilation System in a mine fire zone

YANG Shengqiang[1,*], PANG Weidong[2], WEN Hu[3], YU Baohua[4], MA Zhihe[4], HUANG Ruiling[1]

[1]State Key Laboratory of Coal Resources and Mine Safety, School of Safety and Engineering, China University of Mining & Technology, Xuzhou 221008, China
[2]China National Machinery Import & Export Corporation, Beijing 100037, China
[3]School of Safety and Engineering, Xi'an University of Science and Technology, Xi'an 710054, China
[4]Xuzhou Mining Group, Xuzhou 221000, China

Abstract: Based on mine fire fighting practices at the 1110 working face of the Brapukuria Coal Mine, Bangladesh, we introduce and discuss the Y-Inversion Ventilation System, the latest technology used both in mine fire zone management and the unsealing process. This ventilation system can ensure that all miners breathed fresh air, providing protection for them during fire fighting and unsealing the fire zone. On the other hand, adjusting the amount of air at the working face and forming a CO leakage path controlled the state of the fire and as well ensured that the different fire extinguishing measures could be applied successfully. These are all fundamental techniques which ensured successful fire extinguishing and unsealing of the fire zone. We also analyzed the main reasons for the spontaneous coal combustion that occurred at the 1110 working face. Successful application of advanced composite polymer colloidal perfusion techniques, polymer foam MEA perfusion and fire-prevention technology by infusing nitrogen, used in mine fire zone management and unsealing, are presented. We value the experience with these techniques very highly and are of the opinion that these techniques could be widely used in mine fire fighting practices under similar spontaneous coal combustion conditions elsewhere.
Keywords: Brapukuria Coal Mine; coal mine fire zone management; Y-Inversion Ventilation System

1 Introduction

The primary mineable coal seam of the Brapukuria Coal Mine is the VI seam, with a thickness ranging from 24 to 42 m and an average of 32 m. The Brapukuria Coal Mine is a low gas concentration mine, its coal belongs to the class of long flames. It is a non-caking coal but its coal dust is explosive. This grade of coal has a tendency towards "easy" spontaneous combustion, while the degree of moisture content in the coal seam is listed as weak to medium. As well, conditions of high ground and water temperature and humidity are prevalent in its underground environment. The designed scale of production of this coal mine is 1.0 Mt/y. It uses a vertical shaft with a single seam associated with a diphead development method. The primary horizontal elevation is at –260 m and the second at –430 m. It employs a central juxtaposed ventilation system with an exhaust to ventilate the air. Fresh air flows into the underground through the secondary shaft and returns from the main shaft. The delaminated coal seam is extracted by the longwall retreat mining method while the roof of the gob collapses naturally.

The Brapukuria Coal Mine, constructed by the China National Machinery Import & Export Corporation (CMC), is the first large-scale modern coal mine in Bangladesh and is now jointly operated by CMC and the China Xuzhou Mining Group.

Due to spontaneous coal combustion, the 1110 working face was sealed on October 4th, 2005. Two attempts to unseal the working face both failed, one in April 2006 and the other in August 2007. After improving fire fighting techniques it was successfully unsealed the third time, from July 14th to August 12th, 2008. The fire was eventually extinguished and all mechanized mining equipment was safely recovered, with remarkable technical skill, as well as with economic and social benefits.

2 Reasons and characteristics of spontaneous coal combustion in the 1110 working face gob

The spontaneous combustion of the remaining float coal in the gob and the loose top coal was the result

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*Corresponding author. Tel: 86 516 83884238
E-mail address: yangsq@263.net.cn
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of many factors. These factors included features of spontaneous coal combustion, thickness of the coal seam, the type of seam, roof and floor lithology, the layout of the entry, the method of mining, the underground temperature, the ventilation system, air leakage in the gob, the rate of advance of the working face, the period of mining and others factors. The main reasons for and characteristics of spontaneous combustion at the #1110 working face were as follows:

1) Experimental results show that the tendency of the grade of the #VI coal seam is towards "easy" spontaneous combustion, i.e., the fundamental reason of the occurrence at the #1110 working face gob.

2) Considering that both the coal seam and overlying strata are rich in water, an 8 to 10 m thick layer of roof coal was reserved in order to drain the water during the development and production stages in the #1110 working face. This in itself provided abundant physical materials and ample scope for spontaneous combustion.

3) According to the analysis of micro-characteristics of the lithotype of coal seam #VI, the amount of fusains is very high and the structure loose with a low ignition temperature (190~270 °C). This kind of loose structure has a large number of micro-holes that enhances oxygen absorption and is thus easily oxidized under normal temperature conditions and became the source of ignition in playing a "fire-lighter" function during this stage of oxidation[1-4].

4) The more intake air was flowing into the 1110 working face, the more air was leaking into the gob, so that zone of probable spontaneous combustion continued to increase in size. The remaining float and loose roof coal in the gob easily succumbed to natural oxidation and resulted in spontaneous combustion when the rate of advance of the face slowed down[5-6].

5) The 1110 face has both an advanced development entry and a retreat ventilation system, therefore, there were two gob air leakage paths though the seals. In addition, there were another two leakage points: one was located in the upper corner of the face and the other in the low corner of the face where the two sources of leakage converged. There a large number of air leakage points and paths in the gob, which together became an uncontrollable and complex flow field.

6) More than five months of production was lost. Compared with the period of spontaneous combustion (1 to 3 months), there was ample time to accumulate heat energy for a concealed phase to turn into a fast rising temperature phase[7].

7) The instability of the power supply resulted in frequent starts and stops of the main fan, which improves the chances for combustion.

8) Fire pressure caused by natural oxidation also increased the amount of air leakage in the gob and accelerated spontaneous combustion.

9) Due to the high temperature of the surrounding rock, the concealed phase became shorter and shorter.

10) Dehydration of the coal seam increased crack development and also expanded the area of oxidation.

For all of these ten reasons, spontaneous combustion occurred in the 1110 working face gob.

3 Fire extinguishing in the 1110 working face gob

3.1 Analysis of general proposal for fire extinguishing technology

The task of extinguishing fires can be divided into several parts: 1) Developing extinguishing entries. In order to implement fire extinguishing measures successfully, unseal mine fire zones and control spontaneous combustion, the Nos.I, II and III extinguishing roadways were developed at the front of the face, at the rail head crossing and the haulage gate respectively, as shown in Fig. 1. 2) In the preparation stage of fire management, before unsealing the work face, nitrogen and other extinguishing material were infused into the fire zone via extinguishing entries I and III[8-9]. This not only isolated the oxygen, but also decreased the temperature in the fire zone. In addition, an isolation zone was established by infusing colloidal complexes, as shown in Fig. 2[10-12]. 3) At the stage of controlling spontaneous combustion when unsealing the fire zone, the temperature and components of the air in the mine should be measured at fixed intervals and locations, permitting the determination of the status of the fire zone from the measurements; on the other hand, proper and safe unsealing techniques can be carried out in time to control combustion and the amount of air leakage from the fire zone. 4) At the stage of fire zone management and its control after unsealing: fire extinguishing material still needs to be infused into the fire zone including three-phase froth, nitrogen, soluble silicate colloidal complexes and so on. All of this material can decrease the temperature, pack the remaining float coal in the gob and control the rate of spontaneous combustion. Meanwhile, the Y-Inversion Ventilation System was also used to ensure the safety of the working face all the time.

3.2 Analysis of main technical measures used in 1110 working face

1) Continuous infusion of nitrogen into the fire zone to retard spontaneous combustion. In order to keep the fire zone suffocated, continuous and intermittent infusion of nitrogen into the fire zone must be carried out all the time[13].

2) Colloidal complexes made of fly ash and a gelling agent (FCJ12) was perfused into the opening and tailgate of the No.4 middle railway station, with the aim of trying to decrease air leakage[8].