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Prevention and control of coalfield fire technology: A case study in the Antaibao Open Pit Mine goaf burning area, China

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ABSTRACT

It is very difficult to clearly detect the location of a burning area in a coal mine since it is hidden underground. So we conducted research on the distribution of the burning area before controlling it. Firstly, the original drilling technique was used to analyze and determine the loose and scope of caving of burning area through field test, and then obtained the gases and the temperature data in this area were according to the borehole data. By analyzing these data, we found out that the location of burning area concentrated in the loose and caving area; and finally, the location and development of the burning area within the tested area were accurately determined. Based on this theory, we used the ground penetrating radar (GPR) to find out the loose and caving scale in the burning area during the control process of the burning area, and then located the fire-extinguishing boreholes within target which we used to control burning fire in the section. A mobile comprehensive fire prevention and extinguishing system based on the three-phase foam fire prevention and control technique was then adopted and conducted in the burning area which took only 9 months to extinguish the 227,000 m^2 of burning area of 9# coal. This control technology and experience will provide a very important reference to the control of other coalfield fire and hillock fire in the future.

1. Introduction

At present, as a universal disaster during the development and utilization of coalfield, the spontaneous combustion of coal is a common phenomenon in various regions and countries like China, India, the United States, Russia, Australia and Indonesia [1,2]. Very rich in coal resources, North China is China's major base of coal development and the comprehensive utilization, and has made great contribution to China's economic development and social progress. However, the coal seam tends to have spontaneous combustion and generates coalfield burning area and mine fire with large scale, because most coal resource in this region is in an arid or semi-arid environment with a large thickness and is shallowly buried. The burning area has developed very fast with the rapid development of coalfield mining and consequent massive exposure of the coal seam. Approximately 20 Mt of coal reserves are directly burned annually, which corresponds to the amount of Germany's annual hard coal production. Moreover, more than 200 Mt are lost as mineable reserves due to mechanical and thermal destruction. It also directly threatens the safety production in coal mines [3]. Coalfield fire has become a problem in the resource protection, ecological environment, economic development and population, and is also a major problem affecting the continuous development of China's coal resources and sustainable development of the mine area.

Coalfield fire has become a major concern to various governments and international organizations since the United Nations Conference on Environment and Development (1992). The Chinese government has also put emphasis on this issue, and has listed coalfield fire and corresponding environment control problem in North China into "China's Agenda 21" (1994). Researches on China's coalfield fire have been attached with great importance by the Chinese government and the coal industry, and they have listed researches on coalfield fire as key programs for scientific and technological development of China and the coal industry. A seminar on detection, extinguishing and prevention of spontaneous combustion in coal seam under the framework of "Ecological Research for Sustaining the Environment in China (ERSEC)" was held in Beijing 2005, which furthermore showed the great importance the Chinese government has attached to the study as well as prevention and control of the coalfield fire. In the recent 20 years, research teams consisting of personnel from China's coal enterprises, research institutions and universities have worked together to tackle the key problems and achieved many scientific accomplishments both on theoretical researches and practices, which has greatly promoted the control of coalfield fire in China [4–7].

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So far, researches in both China and other countries have focused on detection of the locations and scope of coalfield fires, while fewer researches on effective fire control technologies have been taken. However, the current fire prevention and extinguishing technology cannot satisfy the requirement of safety production. The current approaches to prevention and control coalfield fire include: stripping of the combustion source on the shallow layer, leaking stoppage, grouting, water injection and inerting technology [8–11]. A comprehensive technical plan for the control of burning area must be made to make full use of these technologies, and only in this way the effective control of the burning area can be realized. Based on the optimized control plan, fast control of the burning area has been realized in Antaibao Open Pit Mine by establishing comprehensive fire prevention and extinguishing system, which can provide a good reference to the control of similar coalfield fire in the future.

2. Overview of the burning area

Jingyang Mine, in the Pingshuo mining area of China National Coal Group Corp., is located in the northeast of current mining area of Antaibao Open Pit Mine. Jingyang Mine mainly mined 9# coal seam has a mining area of about 800,000 m^2 and the exploration method is a combination of inclined shaft and adit. For more than 10 years until 1996, the mining method adopted was the room and pillar method. Spontaneous combustion of coal occurred several times during its mining, which was managed in an enclosed way. A disastrous spontaneous combustion of coal occurred in 2008 when the D1300, 1315 and 1330 platforms in the north part of Antaibao Open Pit Mine entered the goaf of the original Jingyang Mine. With the progress of mining in Antaibao Open Pit Mine, the exposed area of raw coal increased, air leakage intensified, thus spontaneous combustion of coal seam became more and more severe. By the end of 2008, the D1315, 1330 and 1345 platforms were surrounded by thick smoke, and open fire was everywhere (Fig. 1). The disaster of spontaneous combustion not only burnt a large amount of coal resources and constrained general progress of the mining; but also produced plenty of harmful and toxic gases which seriously threatened the health of residents. Operating personnel have ever been poisoned by the harmful and toxic gases when operating in the goaf.

3. Distribution and development of the burning area

Loss of original mining data of Jingyang Mine has increased due to difficulty of controlling the burning area. Therefore, several researches should be conducted before controlling the burning area, such as the distribution and development of the burning area, the relation between the high-temperature location and geologic structure of the burning area, the correlation between temperature and gaseous product concentration and the development of the burning area. Having a clear aware of the location and development of the burning area [12–21], can be used to guide the control of burning area of 9# coal in Antaibao.

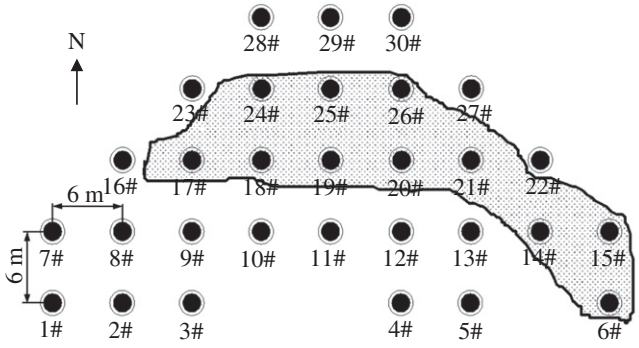

Fig. 2. Schematic diagram of the boreholes layout in the tested area.

3.1. Test area

One area of 9# coal was selected as the test area, and 30 testing boreholes were conducted at an interval of 6 m as shown in Fig. 2. Borehole imaging was conducted to get the distribution of the loose and caving or solid coal scope in this area. The shaded portion in Fig. 2 is the loose and caving area; the rest is the solid coal.

3.2. Data collection

The temperature data and gases in the test area were collected in the boreholes. The gases were analyzed by the chromatographic analyzer after being collected in the air bag, and the collection of temperature data was conducted by using the WRNK191 armored thermocouple. The thermocouple annular tube is a 9Ti material quality with a diameter of about 3 mm. The compensated wire is thermostable and screening type with the measurement error within 1 °C. It is fitted with a quick indicating instrument and can measure a maximum temperature of up to 1000 °C. The complete set of instrument has advantages such as bendable, high pressure resistance, large measuring range, quick response, sturdiness and durability.

3.3. Data processing and analysis

A data analysis software was used to generate the distribution graph of temperature and gases as Fig. 3 shows. As shown in the graph, boreholes with high-temperature were mainly distributed around the area of loose coal, whereas the solid coal region had a relatively low temperature. The temperature in the boreholes reduced with the increasing distance from the high-temperature point, and spontaneous combustion of the coal mainly occurred around the loose area.

Fig. 1. Picture of the burning area site in Antaibao Open Pit Mine.