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Method for prevention and control of spontaneous combustion of coal seam and its application in mining field

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ABSTRACT

Spontaneous combustion of coal seam has been and continues to be a big problem in coal mines. It could pose great threat to the safety of the whole mine and all miners, especially when it occurs in or nearby coal mines. Besides, environment of area surrounded mines during combustion can be threatened where large amount of toxic gases including CO_2, CO, SO_2 and H_2S can be leased by fire in mine. Hence, it is important and significant for scholars to study the controlling and preventing of the coal seam fire. In this paper, the complicated reasons for the occurrence and development of spontaneous combustion in coal seam are analysed and different models under various air leakage situations are built as well. Based on the model and approximately calculation, the difficulty of fire extinguishment in coal seam is pointed out as the difficulty and poor effect to remove the large amount of heat released. Detailed measurements about backfilling and case analyses are also provided on the basis of the recent ten years' practice of controlling spontaneous combustion in coal seams in China. A technical fire prevention and control method has been concluded as five steps including detection, prevention, sealing, injection and pressure adjustment. However, various backfill materials require different application and environmental factors, so in this paper, analyses and discussion about the effect and engineering application of prevention of spontaneous combustion are provided according to different backfilling technologies and methods. Once the aforementioned fire prevention can be widely applied and regulated in mines, green mining will be achievable concerning mine fire prevention and control.

1. Introduction

There are still a large number of coal fires even along with the advance of fire extinguishing technologies. Specifically, spontaneous combustion of coal seam has been and continues to be a big problem in coal mines in China, the United States, Australia and Europe. Approximately 25.1% of key coal mines of China are highly gassy mines, which could result in catastrophic sequel after burning. In recent ten years, serious incidents happened frequently, among them, most of incidents were related to spontaneous combustion [1]. Coal's spontaneous combustion could pose great threat to the safety of the whole mine and all miners, especially when it occurs in or nearby coal mines. Besides, environment of area surrounded mines during combustion can be threatened where large amount of toxic gases including CO_2, CO, SO_2 and H_2S can be leased by fire in mine. In China, every year, the amount of coal that was combusted through coal fires could reach up to 200 million tonnes, which constitutes almost 1% of the global carbon dioxide emissions [2]. Around the world, 40 tonnes of mercury were emitted into the atmosphere due to coal fire while nearly 3% of world's carbon dioxide was estimated to be released from coal fire [3]. Hence, the prevention and protection from coal fires, specifically spontaneous combustion, is of great importance to safe production of mining industry and the global environment.

In this paper, spontaneous combustion in coal seam is studied as it can directly affect mining operations. There will be great harm once there is spontaneous combustion in coal seam in mining field, which results from three reasons. One, fire will pose considerable harm to the safe production and the lives of mining operators as there will be lots of workers in mines while coal seams catch fire. Also, mining companies will suffer from coal resources loss in these seams that has been developed. Besides, living conditions for surrounding citizens will also be largely affected [4,5]. Hence, it is meaningful to study the mechanism of prevention against coal seam spontaneous combustion in mining field.

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Mechanism of coal seam spontaneous combustion is as same as that of a general spontaneous combustion, which will require oxygen. The oxygen, provided by air leakage, is influenced by extraction and other human activities [6]. Meanwhile, fire extinguishment for coal seam spontaneous combustion is quite difficult as it is not easy to remove such a huge amount of heat. Mutual influence among ventilation, mining method and air leakage also perplex this problem. Fig. 1 shows the coal seam spontaneous combustion in mining field in Yunlin, China. Fig. 2 shows the pollution to environment caused by coal seam spontaneous combustion.

It is very hard for direct extinguishment of coal seam spontaneous combustion, because of the buried combustion source and the large amount of water required in extinguishing. Also, the fluidity of water will reduce the effect. Heat as 313.5 kJ will be required to increase the temperature of water amount at 1 kg from 25 to 100 °C, while it will require 2260 kJ heat to transform water at 100 °C to water vapor. Hence, theoretically, it will require 8.12 kg water at 25 °C to extinguish heat produced by combustion of 1 kg coal, assuming the heat release heat by coal at 20,900 kJ/kg. In practice, larger amount of water will be required considering the water utilization rate. Hence, colloid and slurry are applied in extinguishing coal fire because they can cover the coal body and to release the production of heat by suffocating coal fire, however, this method is limited by large amount of water required in colloid and slurry, long processing time and finding accurate location of fire [7].

2. Coal seam fires' spontaneous combustion model

Oxygen provided by air leakage is essential in coal seam spontaneous combustion, so it is unlikely for spontaneous combustion to occur under the current coal seam or other coal seams, and it is also unlikely for methane to accumulate for shallow coal seam. Coal seam spontaneous combustion can be classified into four types based on the influence of spontaneous combustion on mining layer and its air leakage characters.

2.1. Fire caused by surface outcrop of mining-coal seam

Fig. 3 is the demonstration of mining operation in lower mining-coal bed with fire at surface outcrop. If the width and integrity of pillar that isolate mining operation from other coal body can be assured, coal body's surface outcrop will not influence mining operation. The air leakage and heat transfer model is shown in Fig. 4. From this model, it can be concluded that spontaneous combustion of surface outcrop creates leakage absorbing fresh air while toxic hot air flow is released into environment due to the thermal buoyancy effect [8].

2.2. Fire caused by surface outcrop of upper coal seam

If there are multiple coal seams in one mining field, spontaneous combustion in upper coal seam may influence mining operation in lower coal seam.

Fig. 1. Spontaneous combustion in mining field.

Fig. 2. Pollution released by spontaneous combustion.

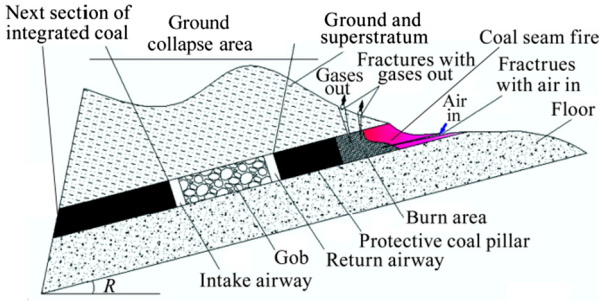

Fig. 3. Mining operation in lower mining-coal bed with fire at surface outcrop.

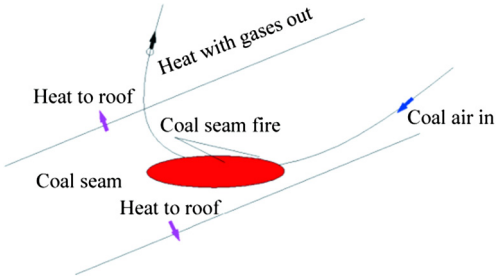

Fig. 4. Air leakage and heart transfer model of spontaneous combustion at surface outcrop.

(1) Situation when spontaneous combustion in upper coal seam that will not influence mining operation in lower coal seam

The situation when spontaneous combustion in upper coal seam that will not influence mining operation in lower coal seam is because that although there is fire at surface outcrop of upper coal seam, the fire will not influence the mining operation in lower coal seam. Because that fire has not connected to mining area, so with certain timeframe, the mining area will not be affected. This situation is shown in Fig. 5.

(2) Situation when spontaneous combustion in upper coal seam that will influence mining operation in lower coal seam

There are two typical situations when spontaneous combustion in upper coal seam that will influence mining operation in lower coal seam. One is shown in Fig. 6. When spontaneous combustion occurs in upper mining gobs or coal seam (due to air leakage) and its location is right above or around mining operation in lower coal seam, the mining operation in lower coal seam will be influenced directly because toxic gases from upper coal seam (or goaf) will enter lower mining area due to negative pressure ventilation in lower coal seam. Another is shown in Fig. 7. In this circumstance, spontaneous combustion happens at surface outcrop of upper coal seam. However, because of the large inclination of coal seam, collapse caused by fire will also influence the mining operation in lower coal seam.