Comparative analysis of sealing effect of different hole sealing processes in coal mine

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Abstract. In order to improve the concentration of gas extraction from boreholes in Liyazhuang Coal Mine, three different sealing technologies, namely bagged polyurethane sealing, self-expanding sealing device sealing and new expansion cement sealing, were tested in the field. It was found that the new expansion cement sealing was the best for boreholes. Further investigation into the meso-characteristics of the combination of the new type of expansive cement and coal wall shows that the new type of expansive cement for mining has a compact overall structure, strong articulated ability to the coal body, and can effectively seal the hole and fissure of the coal body with superior sealing performance.

1. Introduction

Borehole extraction is gas prevention and control of gas disaster in coal mine, coal bed methane development and utilization of the main technical means [1,2]. In coal mine gas drainage work, drilling sealing technology has always been a difficult problem to restrict gas drainage [3-5]. In terms of hole sealing materials, it has experienced the process of clay, ordinary cement mortar, conventional polyurethane, expansive cement and flexible paste materials for hole sealing, and the hole sealing way has also evolved from atmospheric pressure hole sealing to pressure-holding hole sealing [6,7]. To test a variety of hole sealing process of hole sealing in effect at the scene, looking for a good sealing, long sealing time, strong operability of hole sealing process, test the bags, respectively, in Liyazhuang coal mine hole sealing. The expansion type openings for new expansive cement sealing holes and hole sealing, and by investigating the changes in the concentrations of the test drilling of hole sealing process of extraction effect is analysed. Finally, combining with the characteristics of different hole sealing material microstructure observation, we have researched on the different hole sealing material on the properties of borehole sealing effect.

2. Introduction of each hole sealing processes

2.1. Bag polyurethane

Polyurethane is a kind of sealing material commonly used in coal mine gas extraction in China. It is widely used in gas extraction drilling and sealing operation in China because of its convenient and fast operation. In this test, two kinds of bagging polyurethane, namely rapid foaming type (hereinafter referred to as fast material) and ordinary type (hereinafter referred to as slow material), were prepared.
The hole sealing process is shown in Figure 1. Firstly, the fast material is arranged at the appropriate position of the nozzle and the tail of the extraction pipe, and then the appropriate amount of slow material is evenly arranged between the fast material. Taking advantage of the time difference caused by the different reaction rates of fast feed and slow feed, the fast feed will react and foam at the suction nozzle and pipe tail to form a "baffle" with certain pressure. When the slow material starts to foam, due to the extrusion action of the "baffle", the slow material is limited to react in a fixed space, and it is constantly squeezed into the hole sealing section of the borehole cracks, blocking the borehole leakage channel.

2.2. Self-expanding hole packer

The self-expanding hole packer is a relatively new hole sealing method at present. The self-expanding hole sealing device is mainly composed of a suction pipe and an elastic expansion bag with chemical reaction liquid sealed. When sealing the hole, water is first injected into the elastic expansion bag from the water injection port. After the water and the chemical reaction liquid are mixed evenly, the expansion reaction occurs rapidly, and the volume of the reaction liquid increases continuously. Finally, the elastic expansion bag is broken, and the reaction liquid enters the borehole immediately, and the gap between the extraction pipe and the borehole is blocked to achieve the effect of sealing the borehole. Insert flared connection is adopted between the extraction pipes. The hole sealing process has the advantages of fast sealing speed, simple operation, rapid reaction of expansion fluid and high sealing efficiency.

2.3. A new type of expansive cement sealing hole

Aimed at the shortcoming of ordinary cement plug hole, this experiment adopts the new type mining expansion cement plug hole, at the beginning of the material in thin, easy to grouting into the solution, slurry after injection hole to hole circumferential crack seepage, and has thickened in a short time, and the swelling volume, intensity increases gradually, after solidification hole sealing materials closely together with coal, Due to the excellent expansion property of the sealing material, the possibility of new crack formation due to material dehydration is avoided.

Used in the process of test, "a wall of the two note" hole sealing way, first of all to bundle expansion material on both ends of drilling hole sealing section, and make its rapid response, thereby in drilling hole sealing form solidification foamy plug on both ends of the segment, and then in the middle of the two plug buried beforehand good grouting pipe is used to change the new mine expansive cement injection hole sealing section, In this way, the new type of mine expansive cement can only expand in the restricted space, and the slurry can only penetrate radial to the borehole, thus sealing the micro-cracks around the borehole. The hole sealing process is shown in Figure 3.
3. Analysis of industrial test results

This test site was selected to carry out in 2-6081 transport lane of 2-608 working face of Liyazang, which is located in No.2 coal seam +355m level No.6 mining area. The mining surface elevation is +260~+290m, the burial depth is +556~+615m, the coal body sturdiness coefficient is 0.6~1, and the coal seam gas pressure is 0.54MPa. The gas content is 6.55m³/t, the average thickness of coal seam in working face is 3.32m, the coal seam inclination Angle is 5°~16°, the average is 7°, the total length of 2-6081 transport lane is 654.3 m.

The total construction of 9 test drilling holes, including bag polyurethane hole sealing, self-expanding hole sealing device hole sealing, new type of mine expansive cement hole sealing hole 3, the layout of the drilling holes are as follows: all the 9 holes are horizontal drainage holes of this layer, the spacing of drilling holes is 3m, the design depth of drilling holes is 100m, the diameter of drilling holes is 94mm. After the completion of hole sealing, the gas extraction concentration of each borehole was investigated for a period of 3 months, and the comparison curve of the average concentration of the three hole sealing processes was drawn according to the measured gas extraction concentration (the concentration data of each hole sealing process every day are the average of the concentration data of the three boreholes), as shown in Figure 4.

It can be seen from Figure 5 that the sealing effect of the new type of mine expansive cement is obviously better than that of bagged polyurethane or self-expanding type sealing device. In the period of 3 months of investigation.

1) using the new mine expansive cement sealing three drilling, its average concentration of the gas extraction is always over 50%, and no obvious attenuation concentration, using bags and borehole expansion type sealing hole opener seal, as the gas extraction, there is an obvious attenuation, its extraction concentration level was decreased to 20% or so.

2) the new mine expansive cement hole sealing and bag polyurethane sealing holes are used to seal hole sealing materials in a fixed space expansion of hole sealing way, namely the holding type hole sealing way, you can see from figure 5, polyurethane hole sealing and the expansion type bags sealing hole opener hole sealing hole sealing for expansion of chemical materials, density of attenuation had a...
similar regularity. However, the extraction concentration of the bagged polyurethane hole sealing hole sealed by the pressure-holding hole sealing way is higher than that of the self-expanding hole sealing hole sealed by the atmospheric pressure sealing way.

3) adopt new mine expansive cement sealing borehole, its extraction effect is much better than other hole sealing process, the reason mainly has the following two points: ① cover pressure type hole sealing way, grouting slurry was sealed inside fixed space, under the effect of grouting pressure, the hole sealing materials into the closed around the borehole fissure, have the effect of plugging drilling leakage passage. ② volume expansion occurs after the initial setting of the grouting material, resulting in expansive force. Under the action of the expansive force, the cracks in the borehole are continued to be compacted and filled, further reducing the air leakage channel. With the solidification of the grouting material, the expansion force becomes larger and larger, which plays a supporting role on the borehole, limits the deformation of the borehole and keeps the stability of the borehole.

4. Microstructure observation of different sealing materials
In order to more accurately understand the meso-characteristics of different pore-sealing materials in the reaction process and the permeability of coal body, the Z650 video electron microscope was used in this paper to compare and analyse the microstructure and permeability of chemical expansion materials and new type of mine expansion cement combined with coal wall. The following steps were taken in the test: ① A block of coal sample was taken and a simulated borehole was made in the coal sample with a diameter of 50mm and a depth of 300mm. Two boreholes with better perforation were selected as comparison test boreholes, which were marked as 1 # and 2 # boreholes respectively. ② Pour the polyurethane mixture into the No. 1 drilling hole and inject the mineral expansive cement mixture into the No. 2 drilling hole. ③ The two samples were placed in the same environment for 2 weeks. After the expansion cement for mining was completely set, two boreholes were cut in radial direction. The video electron microscope was used to observe the mesoscopic characteristics of the two materials and their combination and penetration with the borehole wall.

Figure 5. The combination of polyurethane and coal wall

Figure 6. Combination of expansive cement with coal wall

It shows the 200 times magnified image of the joint of polyurethane material and coal wall after the complete reaction in Figure 5. It can be seen that after the expansion reaction of polyurethane material, honeycomb bubble structure is formed inside, and the bubble diameter is between 100 and 400μm. In polyurethane materials and coal wall junction, the cellular bubble diameter is larger, polyurethane material cannot enter into the micro (crack) of coal pore, bonding of coal wall only smaller coal particles, in the order of coal wall surface to form single bubble chamber array, this suggests that the polyurethane materials on the permeability of coal is poor, and combined with the coal wall surface is not very stable, In the process of drilling gas extraction, due to the continuous action of ground stress and negative pressure, the single layer bubble array at the junction of polyurethane material and coal wall will inevitably rupture or even fall off, thus forming a new air leakage channel and reducing the extraction concentration.

It is a 200 times magnified picture of the joint place between the new type of mine expansive cement and the coal wall after complete solidification. It can be seen that the overall structure of the material
after solidification is compact without connected holes or cracks from Figure 6. There is no obvious boundary between the pore-sealing material and the coal wall, and the situation that the pore-sealing material enters into the coal body along the crack of the coal wall can be clearly observed, indicating that the material has a strong permeability to the coal body at the initial stage of coagulation. As the material solidifies continuously, the material and the coal wall are more closely combined. In the process of gas extraction, the leakage and infiltration of the gas in the borehole and the air in the roadway through the crack circle around the borehole are effectively blocked.

5. Conclusion
1) Through the investigation of the drainage concentration of the three holes sealing processes, it can be seen that the hole sealing process combining the "two plugging and one injection" sealing method with the new type of mine expansive cement sealing material has the highest gas extraction and the best sealing property of the hole.

2) For bagged polyurethane and self-expanding hole sealing device, both of which are chemical expansion materials, the gas extraction concentration attenuation has a relatively similar law. However, when the pressure holding hole sealing method is used to seal the borehole, the extraction concentration is higher than that of the borehole sealed by atmospheric pressure sealing method.

3) By observing the microstructure of the joint between the chemical expansion material and the new type of mine expansion cement and the coal wall, it is found that the polyurethane material forms a cavity array with a single layer of bubbles arranged on the surface of the coal wall, which has poor permeability to the coal body, and the joint surface with the coal wall is very unstable. After solidification, the whole structure of the new mine expansive cement is compact, and there is no obvious boundary between the cement and the coal wall. The material has strong permeability to the coal body, and effectively blocks the gas leakage phenomenon in the borehole during the gas extraction process.

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References
[1] Cheng Y P, Fu J H, Yu Q X. Development of Gas Extraction Technology in Coal Mines of China[J]. Journal of Mining & Safety Engineering. 2009,26(2):127-129.
[2] Wang Z F, Liu J. Discussion on the problems and countermeasures of gas extraction in coal mines in China[J]. Safety in Coal Mines. 2005,36(3):29-32.
[3] Xu L C. Study on Improving the Sealing Effect of CMM Drainage Boreholes and Its Application[J]. China Coalbed Methane. 2008,5(1):23-24.
[4] Zhang C Y, Chen J, Song X L. Study and Application of Pressurized Grouting Borehole Sealing Technology[J]. Coal Engineering. 2011,3:39-40.
[5] Ba Q B, Zhao X S, Liu Y B. Research and application of hole sealing technology with pressurized grouting in soft coal seam bedding drilling[J]. Coal Engineering. 2017,49(07):61-63.
[6] Chen X, Liu Y B, Li Y Y. Application of Grouting Sealing Technology with Pressure in Wangjiazhai Coal Mine[J]. Industrial Safety and Environmental Protection. 2017,43(05):69-71.
[7] Sun W B, Guo B B, Lu Q M. Effects of SDS on properties of gas extraction hole sealing material[J], China Safety Science Journal. 2018,28(07):88-94.