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Application of foam technology for dust control in underground coal mine

Ren Wanxing [a,b,c,*], Wang Deming [a,b,c], Guo Qing [c], Zuo Bingzhao [c]

[a] State Key Laboratory of Coal Resources and Safe Mining, China University of Mining & Technology, Xuzhou 221008, China
[b] Key Laboratory of Gas and Fire Control for Coal Mines, China University of Mining & Technology, Ministry of Education, Xuzhou 221008, China
[c] School of Safety Engineering, China University of Mining & Technology, Xuzhou 221116, China

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ABSTRACT

In order to effectively control the dust in the underground coal mine, this study proposes and develops a new technology for dust control by foam, and briefly demonstrates the advantage of the foam technology for dust control, such as the good isolation performance, large contact area, high wetting ability, strong adhesion and so on. Besides, the details of the technology are introduced, including the foam agent, foam generator, and foam production process. Then the paper studies the relationship between the foaming agent concentration and liquid surface tension, and explains the principle of the foam generator. The technology is applied in heading face. The application results show that the foam has a remarkable effect on dust control in underground coal mines.

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1. Introduction

Dust is one of the main disasters during the coal production [1,2]. The miners chronically inbreathe the coal dust, especially the respirable dust, which does serious harm to the miners' health and makes them become pneumoconiosis patients. With the popularization of the mechanized coal mining in recent years, the amount of the coal dust increasingly grows in the underground mine, which brings the potential dangers to the safety in mining production. According to the statistics of Ministry of Health, there had been more than 310 thousand coal miners who suffer from pneumoconiosis by the end of 2007, reaching 50% of the whole pneumoconiosis patients in China. Every year, more than 57 thousand miners suffer from the illness of pneumoconiosis, and 6000 miners died on average per year. The report of China State Administration of Work Safety in *Eleventh Five-Year Plan* of *Coal Mine Safety* also shows the direct economic loss that reaches 1 billion yuan because of pneumoconiosis in the coal industry every year [3–7]. In addition, coal dust is the main dangerous source of explosive disaster. Statistical data shows that 106 coal dust explosions have taken place in China from 1949 to 2007, resulting in 4613 casualties [8].

To control the coal dust, a number of methods have been widely used. The most popular technologies are ventilation, water spray, water infusion, water/wetting agent spray and dust-collecting fan [9–14]. These technologies had played an important role in dust prevention, but they have limitations. For instance, the water infusion requires complex equipments and a large amount of water. When using water spray, the nozzle is easy to be blocked, and it leads to the reduction of the ratio of dust precipitation. As for using dust-collecting fan to fall dust, the equipment structure is complicated and the volume is also large. What's worse, the volume of wind which can be dealt with is limited.

To overcome these limitations, the authors developed the foam technology and equipment. Practical application shows that the dust hazard of working face is efficiently controlled by the foam technology, so there is great prospect of wide application of this technology.

2. Features of foam technology for dust control

The foam used for dedusting is composed of air, water and foaming agent. The surface tension of water reduced when foaming agent was added. Then abundant small and homogeneous foam is produced by the foam generator, and then sprayed in the air or on the surface of dust sources. Compared with traditional technologies, the foam technology for dust control has the following remarkable features.

When using water spray, regardless of the fineness of the droplets, there always exist "empty spaces" between the water

* Corresponding author at: State Key Laboratory of Coal Resources and Safe Mining, China University of Mining & Technology, Xuzhou 221008, China. Tel.: +86 13775883564.
E-mail address: rwxcom@163.com (W. Ren).

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droplets. The respirable dust particles will easily "escape" through these "empty paths". In addition, the foam can cover the dust source without "empty space", which can prevent the dust from spreading outside effectively. When the foam is formed, the whole volume and area of foam film will become large rapidly. Compared to water spray, high expansion foam will cover much more space with the same amount of water. It can greatly increase the probability of the collision between foam and dust. The film of the foam contains foaming agent, which can greatly reduce the surface tension of water. And the dust wettability is improved quickly. As a result, the dust will be wetted very efficiently. Moreover the adhesiveness of foam is very strong. Once the foam and dust collide, the dust will adhere to the foam quickly and firmly. Thereby, it will catch the dust particles much more easily [15–19].

3. Key points of foam technology

The foam is composed of air, water and foaming agent. The key points of the technology are to develop the foaming agent and foam generator.

3.1. Foaming agent

In order to meet the demand of foaming and dust removing, many kinds of surfactants are screened out. The multicomponent experiments are carried out in laboratory, and a certain amount of auxiliary agent was added. The mixed system named new foaming agent was formed and has a good effect on reducing the surface tension of water, and the dust was wetted easily. Meanwhile, the foaming multiples will become larger obviously. Fig. 1 shows that: with the change of the concentration of new foaming agent, the surface tension of the liquid changes respectively. From these curves, the most adoptable concentration of the foaming agent is about 0.5%.

The efficiency of dust removing has direct relation with the dust wetting performance of the foaming agent. In order to investigate the wetting performance, rock dust, which weights 10 g and 150–200 mesh, is selected in laboratory. The wettability of the foaming agent for the dust is evaluated by water film flotation which is by measuring the time of a certain amount of dust sinking into the water or solution. The dust was sprayed on the surface of water (or solution). The experimental procedures are as follows: first, prepare 5 kinds of 200 mL solutions in 500 mL cylinder, and they are clear water, solution A, solution B, solution C and solution of new foaming agent. The concentration of every kind of solution except clear water is 0.5%. Second, take 9 mL every kind of solution with transfer pipette into 5 measuring cups. When the liquid level in the measuring cups keeps stable, 0.2 g rock dust is weighted on the electronic balance with an accuracy of 0.01 g, and then sprinkled them to the measuring cups. Then, the time is measured, when the dust all is immersed in the clear water or solution. Last, the above steps are repeated three times to take the average.

Fig. 2 displays the comparison of surface wettability among clear water, the new foaming agent and the other three surfactants for rock dust. As shown in Fig. 2, it is obvious that the new foaming agent has the best surface wettability for rock dust under the same conditions.

3.2. Foam generator

The foam for dust control is produced by the foam generator. So the foam generator is one of the main components of the foam technology for dust control.

The structure of foam generator usually used contains net and filler form. But their working conditions are not suitable to coal mine. Although there are reports about other types foam generator at home and abroad, the foaming multiple is low, and cannot meet the need of dust control [20–22].

In the design process of the foam generator the following four factors should be taken into consideration: first, make the gas–liquid two-phase fluid form turbulent stream as far as possible; second, make the liquid scatter increase the contact superficies with the gas; third, increase stirring intensity of the gas–liquid properly and let them collide with each other to form bubbles; fourth, make sure that there are no internal moving units and keep the pipe unobstructed.

According to the four key points mentioned above, new foam generator was developed based on the theory of turbulent jet. The principles of the foam generator are used to make full use of the high pressure of water and compressed air in underground mines, as well as the characteristics of high-speed and low-pressure of venturi tube at its throat. The static pressure of water can be transformed into velocity pressure when the foam solution flows through the foam generator. Because of the entraining effect of the jet, the compressed air was pulled in the jet core. In order to increase the contact surface between gas and liquid, several air holes and the disturber at the diffusion section of venturi tube were set. Then the two-phase gas–liquid jet flow impacted the disturber with high-speed, and the turbulence was formed behind the jet disturber in foam generator, therefore the gas and liquid can be mixed fully. Besides, some barrier boards were set behind the vortex generator to raise the intensity of the gas–liquid mixture. Then the flow run through the baffle area which was the posterior structure of the foam generator. It can make the air and liquid mix further, and then stable and high-quality foams are formed.

3.3. Producing flow of foam

Fig. 3 shows the producing flow of the foam for dust control. First, the water was pulled in the pipeline through pump or gravity from the ground surface. The foaming agent was added proportionately

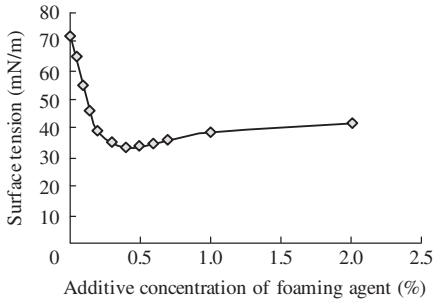

Fig. 1. Relationship between concentration of foaming agent and surface tension.

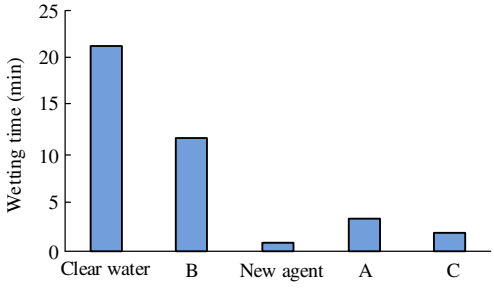

Fig. 2. Comparison of surface wettability of clear water, three surfactant and new foaming agent for the rock dust.

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