



Application study on complex wetting agent for dust-proof after gas drainage by outburst seams in coal mines



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ABSTRACT

After gas drainage, the outburst seam is dry and, consequently, during subsequent mechanized mining, unwanted dust production is extensive. Because the hard dustfall typically has a small particle size it contains a high percentage of respirable dust. Considering these factors, this paper improved the efficiency of dustfall by reducing the surface tension of the liquid used as a wetting agent, then configuring five kinds of wetting agents by adopting various doses and types of surfactants, neutral inorganic salts and chemical additives, etc. After purchasing DA-85 and SRJ-1 wetting agent, the surface tension and critical micelle concentration of seven kinds of wetting agents were measured using the capillary rise method. Wetting agent A was confirmed to have the best comprehensive effect. The experiments were optimized by measuring and comparatively analyzing contact angles of pure water, SRJ-1 wetting agent and wetting agent A on the surface of different coal samples using a contact angle measurement instrument (HARKE-SPCA). By comparative analysis, dust-proof effects of seam, dynamic pressure water infusion and high-pressure spray in the tunneling face at the Daning coal mine using pure water, wetting agent SRJ-1 and A, it was determined that after using wetting agent A, the average dust concentration in the place of the mining machine driver, 10 m and 110 m away from the tunneling front is approximately 300 mg/m³, 240 mg/m³ and 100 mg/m³, respectively. This practice increased the dust-proof efficiency dramatically and achieved a good comprehensive dust-proof effect.

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1. Introduction

In recent years, tunneling mechanization has constantly improved as mining methods and processes have developed with a focus on intensive production and high yield. Along with the increase in productivity, there is a sharp increase in the accumulation of dust on the workings faces, especially respiratory dust whose particle size is less than 5 μm and is therefore extremely harmful to human health and can lead to coal dust explosion [1]. In the process of rapid tunneling of a large cross section, the dust concentration can be as high as 1000–3000 mg/m³ where respiratory dust, in particular, accounts for a high proportion of the dust concentration overall [2–4]. For a long time, coal seam water injection to suppress dust and sprinkling water for dust elimination or a combination of the two measures have been widely used. Experiments show that dust-proof efficiency of respiratory dust is only about 30–50% when the sprinkling water technique is employed.

In comparison, dust-proof efficiency of respiratory dust can reach higher than 65–75% when more comprehensive dust-proof measures are adopted [5–8].

At home and abroad, a lot of research has been conducted in an effort to improve dust suppression techniques and methods. Although some progress has been made, the phenomenon still exists. The problem of high dust content in working places, low efficiency in capturing respiratory dust and excessive concentrations of coal dust persists [9–13]. Two methods widely used abroad to improve dust collection efficiency that involve changing the water's surface tension by wetting agents and using chemical additives, have become active areas of research for application at home [14,15]. Hu applied surface tension and suction settlement methods to configure wetting agent SRJ-1 with good performance results [16]. Zeng increased the dust-proof to 91% by using the complex wetting agent in the industrial experiment of tunneling faces [17]. After Chongqing Coal Research Institute applied the high-productivity dusting wetting agent to Yangquan Xinjing coal mine, the dust-proof efficiency increased 43.1% compared with the ordinary method of sprinkling water, which markedly improved

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working the environment at mining faces [18]. Huainan synthetic materials plant imported dust-proof agent from the American Wen-Don company, developed DA-85 dust-proof agent, and applied it to the tunneling face in Gushuyuan coal mine and Pingdingshan I coal mine. As a result, the concentration of respiratory dust was 62–96% less than when just water was used [19].

Based on these positive results, the highly efficient wetting agent method was applied to the Daning coal mine which had the typical problems of high dust production when tunneling a large cross section after gas drainage by outburst seam. The dust was minimized by application of a comprehensive dust suppression method which included drilling a hole to add the wetting agent and spraying water mixed with the wetting agent on the tunneling faces. The successful optimization of the dust control is directly related to the importance of protecting the security of the mine and health of the miners.

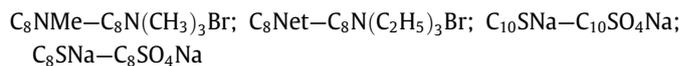
2. Complex wetting agent and effects analysis

A wetting agent refers to a substance which can reduce water surface tension or interfacial tension, and allow a greater degree of interaction between the water and a solid substrate which cannot be dissolved in water. Its main ingredient is surfactant, some chemical additives and inorganic salt which can help to develop some new features, so that the wetting agent's effect can be optimized [20,21]. To determine the optimal mixture proportions having the best wetting effect and cost performance, the character and mixture principles of surfactant and inorganic salts were researched and five kinds of wetting agents were made. The optimal mixture proportions were determined by studying the wetting agent's surface tension, critical micelle concentration (CMC), contact angle and other parameters. Final determination of the optimal mixture proportions were made by comparative analysis of the experimental results.

2.1. Mixture principles and methods

Mixture methods of the wetting agents are divided into three main categories; surfactant with neutral salt, ionic and non-ionic surfactant, anionic and cationic surfactant. After mixing, it is expected that wetting agents will have improved performance, lower cost and less negative impact on the environment [22,23]. Traditional wetting agents usually use the first two categories. The third category, anionic and cationic surfactant, has been developed and adopted slowly, and represents a neutralization approach. A large number of experiments were conducted using an unequal mole ratio mixture, polyoxyethylene chain, nonionic, amphoteric surfactant, neutral inorganic salt and other adjusting methods. The mixture methods can make an anionic and cationic surfactant has a strong interaction in the mixed solutions, resulting

in the creation of high surface activity. The specific comparison is shown in Table 1.



According to the principle of complex wetting agent, we selected cationic surfactant, polyacrylamide (CPAM), dodecyl trimethyl ammonium bromide (DTAB, $\text{C}_{12}\text{H}_{25}(\text{CH}_3)_3\text{NBr}$), cetyl pyridine chloride (bromide). Anionic surfactant: succinic acid sodium diisooctyl sulfonic acid, sodium dodecyl sulfate (SDS), dodecyl benzene sulfonic acid sodium (SDBS), laurel alcohol ether phosphate (MOA-3P, $\text{RO}(\text{CH}_2\text{CH}_2\text{O})_3-\text{PO}(\text{OK})_2$). Nonionic surfactant, polyethylene glycol (PEG-4000), polyether modified silicone oil (DY-ET102), polyoxyethylene sorbitan fatty acid ester 60 (Tween-60), fatty alcohol polyoxyethylene ether (AEO-9, $\text{C}_{12}\text{H}_{25}\text{O}(\text{C}_2\text{H}_4\text{O})_9$). The main solution is diluted to 1% and mixed in different ratio, where a certain amount of additives are added. After preparing five different wetting agents labeled A, B, C, D, E, many experiments were conducted and the wetting effects were analyzed.

2.2. Measurement of surface tension and critical micelle concentration

The capillary rise method was employed to measure the surface tension of seven different wetting agents (A, B, C, D, E, DA-85, and SRJ-1) using the experimental setup shown in Fig. 1. First, in order to calibrate the system, measurements were made to determine the surface tension of pure water. To prepare a comparative analysis of the wetting characteristics, each different wetting agent was measured three times at the end of a ten minute period each time. A record was kept of the water column higher than the water surface elevation. The surface tension was calculated according to the average water column measurements. The results are given in Table 2.

According to Table 2, the water's surface tension is larger, and 2–3 times as much as the wetting agent solution. The surface tension of the commercial wetting agents DA-85 and SRJ-1 was found to be slightly larger than that of the prepared complex wetting agents. The measured height of the water column of the complex wetting agent was found to be $E < A < D < C < B < \text{SRJ-1} < \text{DA-85} < \text{H}_2\text{O}$. The order of surface tension was found to be $E < A < D < C < B < \text{SRJ-1} < \text{DA-85} < \text{H}_2\text{O}$, that is to say, surface activity of each one $E > A > D > C > B > \text{SRJ-1} > \text{DA-85} > \text{H}_2\text{O}$; thus, the surface tension of wetting agent E is minimal. In addition to selecting the wetting agent with the minimal surface tension, the overall cost and the critical micelle concentration are also important considerations in determining the optimal wetting agent.

To determine the critical micelle concentration, the surface tension was measured using the capillary rise method while continuously diluting the wetting agent. The turning point concentration was reached when the water column was observed to change and this was taken as the critical micelle concentration of the particular wetting agent. The experimental results are shown in

Table 1
Anionic and cationic surfactant mixed critical micelle concentration and surface tension (25 °C).

Surfactant	CMC (mol/L)	γ_{CMC} (mN/m)
C_8NMe	0.26	41.0
C_8SNa	0.13	42.5
C_8NEt	6.0×10^{-2}	40.0
C_{10}SNa	3.2×10^{-2}	38.0
1:1 $\text{C}_8\text{NMe}-\text{C}_8\text{SNa}$	7.5×10^{-3}	23.0
1:1 $\text{C}_8\text{Net}-\text{C}_{10}\text{SNa}$	4.5×10^{-4}	22.0
1:1 $\text{C}_8\text{Net}-\text{C}_8\text{SNa}$	8.2×10^{-3}	27.0
10:1 $\text{C}_8\text{NMe}_3\text{Br}-\text{C}_8\text{SNa}$	3.3×10^{-2}	23.0
1:10 $\text{C}_8\text{NMe}_3\text{Br}-\text{C}_8\text{SNa}$	2.5×10^{-2}	23.0
1:50 $\text{C}_8\text{NMe}_3\text{Br}-\text{C}_8\text{SNa}$	5.0×10^{-2}	25.0



Fig. 1. Capillary rise method to measure the surface tension.

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