Preparation of high-temperature resistant and environment friendly dust suppressant

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Abstract—In order to make the grindability of the semi-coke better, some manufacturers choose to dry the semi-coke at a higher temperature after the preparation. The existing dust suppressants in the market fail due to the high temperature in the drying process, causing extremely serious dust in the plant, which greatly endangers the health of workers. A high-temperature resistant and environment friendly dust suppressant is developed to solve the above problem. This dust suppressant can exist stably at 120 ℃, and it has excellent dust suppression performance.

1. Introduction

In the process of coal transportation and storage, a large number of coal particles and coal dust will be produced. A large amount of coal dust exists in the environment, which will cause serious pollution to soil, water resources, atmosphere and other aspects. For example, when the dust enters the soil, trace elements in coal will also enter the soil. When its quantity reaches the limit value of soil absorption, trace elements become pollutants harmful to the environment, which would change the soil composition, structure and function. Worse, it can lead to the depletion and destruction of soil resources [13]. The existence of excessive coal dust will also harm human health. If working and living in a high dust environment for a long time, people will have a higher risk of rhinopharyngitis, upper respiratory tract infection and other diseases.

The industry generally adopts the means of dust suppressants to solve the above problems. On the one hand, dust suppressant plays the role of wetting, bonding and anti-scouring. On the other hand, the dust suppressant has good film-forming characteristics, which can effectively inhibit the dust and form a protective film on the material surface [6]. Although there are many kinds of dust suppressants developed in decades, the research of dust suppressants be used in high temperature environment is very rare. For example, some semi-coke manufacturers choose to dry the semi-coke at 100℃ or higher temperature to improve the performance of the semi-coke. Commercial dust suppressants will fail due
to the high temperature during the drying process, resulting in extremely serious dust, which greatly endangers the health of workers. Therefore, this paper aims to study a new type of dust suppressant, which has the advantages of high-temperature resistance, good dust suppression effect and no environmental pollution. It is particularly important that it can be completely suitable for high temperature environment such as semi-coke drying.

2. Materials and Methods
There are many factors to be considered in the research of high-temperature resistant dust suppressant. The performance and cost are the core of the research. On the one hand, in order to make the heat-resistant of the dust suppressant good enough, the raw material in the dust suppressant with high-temperature resistant is a necessary factor; On the other hand, in order to meet the needs and benefits of industry, low manufacturing cost is also the main consideration.

2.1. Coagulant
Organic polymer materials are usually selected as coagulant. Organic polymer can absorb many particles and forms hydrogen bonds with them because of its high polarity. So, the cohesion is increased between the particles. The coagulant solution also has viscosity, and the higher the concentration, the greater the viscosity. But the main disadvantage of coagulant is its high price.

Organic polymer usually has high polarity, which can absorb many dust particles and form hydrogen bond with them. Then, the particles can be bridged by hydrogen bond. In this way, one polymer can absorb many particles, thus the cohesion is increased between the particles. The coagulant solution also has viscosity, and the higher the concentration, the greater the viscosity. But most of the price is slightly expensive.

Polyvinyl alcohol (PVA) is a commonly used coagulant. PVA has good film-forming and adhesion, which is widely used in textile, paper, coating, wood, leather and other industries. Adding PVA to the chemical dust suppressant can increase its permeability, effectively condense the coal dust particles and inhibit the coal dust flying \[^{14, 15}\]. A certain concentration of PVA can be used as dust suppressant alone, but its cost too high to be widely used.

2.2. Binder
Having a strong adhesiveness on coal dust particles is one of the most important properties for binder. The components of the binder also need to have the following characteristics: no toxicity to biological population, no pollution to the environment, simple and easy construction process, and meeting the requirements of economic and social benefits. When the binder used with the coagulant, the binder can increase the viscosity of the coagulant solution. Even the water in the solution evaporates, the binder can also fill in the gaps between the dust particles to make the particles connect more closely. The shell formed by the binder has better performance, and the dust suppression effect is correspondingly good.

Corn starch with good viscosity was selected as the binder in this experiment. Starch comes from a wide range of sources, and it’s cheap. The starch solution has a certain viscosity and can also form film. However, when used it alone, the film formed by coagulation is brittle, which can be overcome when it combined with the coagulant \[^{1, 2, 4}\]. The common disadvantage of starch is that its heat resistance is not good enough, and it will pre gelatinize at about 50°C. If the moisture content exceeds 40% in the starch solution, and heated it to 80°C for 10 minutes, which will metamorphosed into gel particles. Therefore, the first thing to do is to modify starch to make it have excellent heat resistance after selecting starch as raw material.

In sum, through the analysis of dust suppression materials, polyvinyl alcohol, modified starch, sodium dodecylbenzene sulfonate and borax were selected as the main raw materials for the bonding dust suppression agent. This dust suppressant product is not only used in the process of semi-coke drying, storage and transportation, but also used in various mining areas, slag dump, building demolition, along the road under construction, cement plants, metallurgical plants and desertification areas.
2.3. Preparation method of dust suppressant

The process flow chart of dust suppressant preparation is shown in Figure 1.

![Figure 1. Flow chart of dust suppressant preparation](image)

The specific preparation steps of dust suppressant are as follows:

1. The film-forming agent and part of water added in the flask-4-neck with stirrer, thermometer, reflux device and heating, keeping it stirring, and we raise the temperature to above 95 ℃ to make it completely dissolved.

2. We reduced the temperature to 30 ~ 55 ℃. Then, we adjust the stirring strength, add emulsifier and react for 20 ~ 30min.

3. The initiator is added to react for half an hour, then the modified starch solution was added three times in proportion. The graft copolymerization is carried out at constant temperature for 1.5h, then the solution cooled to room temperature.

4. A small amount of 2 % borax is added for crosslinking reaction for half an hour. After the reaction, a high temperature resistant coal dust suppressor is obtained.

3. Test Results and Discussions

3.1. The cured layer thickness and the dust suppression efficiency test

The dust suppressant Sprayed on the surface of coal sample. After drying, we take 4 solidified layers randomly, measure the thickness with a scale, and take the average value as the cured layer thickness. Then, the coal sample is heated to measure the thickness change of solidified layer at different temperatures [10].

From Fig. 2, it can be seen that the thickness of the cured layer decreases to a certain extent with the increase of temperature, and it decreases sharply near 80 ℃. It is considered that part of the materials formed by the dust suppressant film deteriorated at 80 ℃. Although the film thickness changes more obviously than other time periods, it is still in a reasonable range. At the same time, it can be seen from the test results that the film thickness has been decreasing with the increase of temperature, the weakening extent is weak. Even in the environment of 120 ℃, the covering film formed by dust suppressor still has enough thickness.

Viscosity is one of the most important characteristics of water-soluble polymer, which has a great influence on the application of curing agent. In this experiment, ndj-8s rotary viscometer is used to study the viscosity and variation of curing agent with different formulations and in different states. It can be seen from the relationship between viscosity and temperature of dust inhibitor in Figure 2 that the viscosity of dust suppressant solution has a linear relationship with temperature at 40 ℃~ 60 ℃ and 90 ℃~ 120 ℃, but the viscosity changes rapidly with temperature at 60 ℃~ 80 ℃. This may be due to the decomposition of some substances in the dust suppressor at 60 ℃~ 80 ℃. The viscosity of the solution is only related to the number of the polymer in unit volume (concentration). At this temperature, due to the deactivation of some substances, meaning the decrease of relative polymer number (concentration), resulting the decrease of viscosity is accelerated. At the same time, the Figure 2 also shows that the dust suppressant still has a high viscosity after 120 ℃.
3.2. Dust suppression efficiency test
The 10 - 30 mesh coal sample is selected, it is dried in oven at 50℃ for 300 min to remove moisture. The appropriate equivalent coal is taken and put in two (300 mm × 210 mm ×30 mm) to make the surface of the coal seam flush with the tray, and weigh them separately, where the mass of coal is \( W_1 \). The two pallets are sprayed with dust suppressant in proportion, dried them in the oven keeping a fixed temperature for 120 min, and then put them into the wind tunnel respectively. In the wind tunnel, keeping the coal seam surface wind speed of 30 m/s, the erosion was carried out for 5 min, and then weighed them respectively. The mass of remaining coal is \( W_2 \). Then, we calculate the wind erosion rate of the sample according to the following formula:

\[
E = \frac{W_1 - W_2}{W_1} \times 100\%
\]  

Where:
- \( E \) -- wind erosion rate of sample;
- \( W_1 \) -- quality of coal before erosion;
- \( W_2 \) -- quality of coal after erosion.

The wind erosion rate of sample 1 is \( E_1 \), and the wind erosion rate of sample 2 is \( E_2 \).

We through the wind erosion experiment, the resistant wind erosion rate of the dust suppressant at different temperatures was tested. As is shown in the Figure. 3, the experimental results show that the resistant wind erosion rate of the dust suppressor changes more gently and the resistant wind erosion rate is less than 0.2% with the increase of temperature, which shows that the resistant wind erosion performance of the dust suppressant excellent. There is a big performance change near 80℃, which is caused by the change of viscosity and film thickness.

4. Conclusion
Through the test, the dust suppressant produced by etherified starch with a high degree of substitution as the main raw material has good heat resistance. Especially when the temperature rises above 100 ℃, the dust suppression maintains good performance, which is an advantage that ordinary dust inhibitors do not have.

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