Removal of fine particles in coal fired power plant by chemical coagulation

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Abstract. The fine particle dust produced by coal-fired power plants is one of the important sources of air pollutants. Wet electrostatic precipitator (WESP) is one of the effective methods to remove fine particle dust. However, the traditional wet electrostatic precipitator still has low collection efficiency for the superfine particle dust. To improve the collection efficiency and the chemical coagulation method is applied to the wet electrostatic precipitator. Experiments are carried out by varying the chemical coagulation agent type, concentration, surfactant species. The results show that: Adding chemical coagulants can promote the coagulation effect of fine particles, and Xanthan gum (XTG) has the best coagulation effect; the concentration of chemical coagulant also affects the coagulation effect and collection efficiency of dust, the optimal concentration of XTG is $1.0 \times 10^{-2}$ g/L; among the surfactants, dodecyl dimethyl benzyl ammonium chloride (1227) has the best effect, and the dust removal efficiency can reach 98.80%. Through experimental exploration, the chemical coagulation method has a good application prospect in wet electrostatic precipitators.

1. Introduction
In recent years, haze weather has occurred frequently and air pollution has become more and more serious. People have begun to pay attention to the problem of air pollution [1]. Air pollution can cause many serious effects, including reduced visibility and health hazards. Fine particle is one of the sources of air pollution, and the emission of fine particulate matter mainly comes from human activities, such as the burning of coal [2]. China is a big country of coal production and consumption. In the recent period, it has been the country that burns the most coal in the world [3]. Among them, the fine particles produced by the combustion of coal-fired power plants are the most, about 35% [4, 5]. Therefore, the removal of fine particle dust generated by coal-fired power plants has become a key area of industrial flue gas dust removal [6]. As the mainstream technology in the current domestic and foreign dust removal technology, the wet electrostatic precipitator technology has the advantages of high purification efficiency, low resistance loss, and so on [7]. However, the conventional wet electrostatic precipitator technology is still low in the collection efficiency of fine particles and dust, and it is difficult to reach the ultra-low emission standard [8].

Taking some chemical means to agglomerate fine particles into larger particles [9], which is commonly referred to as agglomeration technology, can improve the collection efficiency of the wet electrostatic precipitator [10]. In the paper, by changing the use conditions of chemical coagulants, the author studies how to improve the collection efficiency of fine particles in wet electrostatic precipitators, as well as chemical coagulants and their effects on the performance of wet electrostatic
precipitators.

2. Materials and Methods

2.1. Experimental apparatus

2.1.1. Electrostatic precipitator experiment platform
Figure 1 shows the experimental platform for electric dust removal. The electrostatic precipitator can be used for both dry and wet purposes, and is mainly composed of a feeding system, a high-voltage power supply system, a low-voltage control system, a fan system and a discharge dust collection system. In addition to the above five parts, the wet electrostatic precipitator also has a spray system. It can be used for wet ash cleaning.

2.1.2. Particle size distribution system for dust measurement
During the experiment, the BT-9300H laser particle size distribution meter was used to measure the particle size distribution of dust. The instrument has the advantages of convenience, quickness, good repeatability, and wide test range, as shown in Figure 2.

2.2. Experimental methods

2.2.1. The influence of chemical coagulants on the coagulation of fine dust
Test Parameters are selected as follows: WESP working voltage: 40 kV; electric wind speed: 1.0 m/s; water pressure: 0.5 MPa; inlet dust concentration: 95 mg/m³.

(1) Add 5 kinds of chemical coagulants: xanthan gum (XTG), sodium alginate (SA), sodium carboxymethyl cellulose (CMC), polyaluminum chloride (PAC), non-ionic polyacrylamide (PAM). Measure the particle size distribution of dust and select the chemical coagulant with the best coagulation effect.

(2) After finding the best chemical coagulant, prepare the concentrations as $0.1 \times 10^{-2}$ g/L, $0.5 \times 10^{-2}$ g/L, $1.0 \times 10^{-2}$ g/L, $1.5 \times 10^{-2}$ g/L xanthan gum (XTG) solution is tested to measure the particle size distribution of dust.

(3) Add three different kinds of surfactants with the same concentration: sodium dodecyl benzene sulfonate (SDBS), triton (XT-100), dodecyl dimethyl benzyl ammonium chloride (1227), to measure the particle size distribution of dust.
2.2.2. Effect of chemical coagulant on dust removal efficiency

Test Parameters are selected as follows: WESP working voltage: 40 kV; electric wind speed: 1.0 m/s; water pressure: 0.5 MPa; inlet dust concentration: 95 mg/m³.

(1) Five kinds of chemical coagulants (XTG, SA, CMC, PAC, PAM) were selected to determine the dust concentration at the outlet and calculate the dust collection efficiency.

(2) The xanthan gum (XTG) solution with the concentration of $0.1 \times 10^{-2}$ g/L, $0.5 \times 10^{-2}$ g/L, $1.0 \times 10^{-2}$ g/L and $1.5 \times 10^{-2}$ g/L was prepared for experiment. Measure outlet dust concentration and calculate the dust removal efficiency.

(3) Three kinds of surfactants (SDBS, 1227, XT-100) were added to measure the dust concentration at the outlet and calculate the dust removal efficiency.

3. Results and discussion

3.1. Physical properties of the original dust

Before the experiment, a small amount of original dust from coal-fired power plants was taken and its particle size distribution was measured by BT-9300H laser particle size analyzer. The measurement results are shown in Figure3.

![Figure3](attachment:particle_size_graph.png)

It can be seen from Figure3 that the particle size distribution of coal-fired power plants is wide, ranging from 0.2 μm to 115 μm. Dust with particle size less than 4.84 μm accounted for 10% of the total; dust with particle size less than 18.15 μm is accounted for 50% of the total; dust with particle size less than 46.28 μm is accounted for 90% of the total. The dust with particle size less than 100 μm is accounted for 99.8% of the total. The dust with particle size less than 2.5 μm is accounted for 4.29% of the total.

3.2. Dust morphology map of coal-fired power plant

Scan the original dust of coal-fired power plant to observe the morphology and microstructure of the dust. The results are shown in Figure4. As can be seen, most of the dust coal-fired power plants is irregular particle sizes, the majority of these particles was loose state and exist independently between thickening against dust particles becomes large.
3.3. The influence of chemical condensation on dust coalescence

3.3.1. The impact of chemical coagulant types on dust coagulation

Several chemical coagulant solutions with a concentration of $0.5 \times 10^{-2}$ g/L were configured, and water was used as a reference to compare the coagulation effects of different chemical coagulants on coal-fired power plant dust. The results are shown in Fig.5.

It can be seen from Figure5 that when the particle size of the dust is less than 10 μm, the curve moves down significantly, and the cumulative percentage of dust decreases significantly. Particle size distribution becomes wider, the large size of dust develops from nothing. It shows that the chemical coagulant has a coagulation effect on the particle dust of coal-fired power plants. In order to make a more intuitive analysis, use $d_{10}$, $d_{50}$, and $d_{90}$ as the abscissa and the dust particle size as the ordinate to plot. The results are shown in Figure6. As can be seen from Figure6, for $d_{10}$, 5 chemical coagulation solution becomes wider, but little difference; for $d_{50}$, the difference in particle size of different coagulants increases, XTG is 50.00 μm, SA is 44.85 μm, CMC is 42.52 μm, PAC is 39.08 μm, and PAM is the smallest 33.12 μm; for $d_{90}$, XTG is also the largest, with a maximum value of 208.3 μm.

Based on the above analysis, among several chemical coagulants, XTG has the best effect on coal-fired power plant dust.

The reason is as that: XTG is an organic polymer compound, the molecular mass of more than 1 million, the secondary structure is the side chain wound in opposite directions around the main chain skeleton, and maintain a rod-like double helix formed by hydrogen bonds. In addition to the general properties of other long-chain polymers, XTG also contains more functional groups to form a network structure. This unique structure can more effectively trap dust particles. In addition, XTG will become a stable hydrophilic viscous colloid when exposed to water [12], and its solution has the characteristics...
of low concentration and high viscosity. Therefore, XTG has a better effect on dust condensation.

3.3.2. The influence of coagulant concentration on chemical coagulation

The influence of chemical coagulant concentration on the dust coagulation effect is shown in Figure 7. Comparison no addition of chemical coagulation solution, obvious downward curve, indicating that chemical coagulation agent can effectively promote coagulation and dust. For more intuitive analysis, draw Figure 8. It can be seen that in the range of $d<1 \mu m$, the dust content is 1.36%, 1.11%, 0.92%, 0.53%, 0.67% respectively; in the range of $1 \mu m<d<5 \mu m$, the dust content is 3.58%, 2.98%, 2.37%, 2.16%, 2.29% respectively; in the range of $5 \mu m<d<10 \mu m$, the dust content is 7.35%, 6.31%, 4.71%, 4.63%, 4.71%, respectively. In summary, the analytical chemical coagulant has the best coagulation effect when the concentration is $1.0 \times 10^{-2} g/L$.

The reason is as that: As XTG increases from 0 g/L to $1.0 \times 10^{-2} g/L$, the number of agglomerates in the spray liquid gradually increases, which increases the probability of collision with dust particles and the probability of adhesion, and the aggregation effect will be enhanced. When the concentration of XTG continues to increase, the agglomerates attached to the surface of the dust particles have reached a saturated state, and too many agglomerate molecules cannot find a place to adsorb. At the same time, too much agglomerate will also reduce the effective collision of dust particles and agglomerates. Therefore, when the concentration of XTG increases from $1.0 \times 10^{-2} g/L$ to $1.5 \times 10^{-2} g/L$, the effect of dust condensation will not increase but decrease.

3.3.3. The influence of surfactants on chemical coagulation

Add SDBS, XT-100, 1227 surfactants at a concentration of $0.5 \times 10^{-2} g/L$, as shown in Figure 9, and compare the aggregation effects. It can be seen from Fig.10. It can be seen from Fig.10 that when $d<1 \mu m$, the dust content is 0.53%, 0.42%, 0.42% and 0.30%, respectively. In the interval of $1 \mu m<d<5 \mu m$, the dust content is 2.16%, 2.09%, 1.96% and 1.64%, respectively. In the interval of $5 \mu m<d<10 \mu m$, the dust content is 4.63%, 4.56%, 4.23% and 3.56%, respectively. Based on the above analysis, SDBS has very limited effect on dust coagulation, and 1227 has the best effect on dust coagulation.

Analyze the reason: 1227 is a cationic surfactant. The negative surface of the particles and the positively charged surfactant can attract each other, which can significantly promote the coalescence of dust particles. On the contrary, when the anionic surfactant SDBS is added, the colloid in the suspension becomes stable and the particles tends to be dispersed. This is because the dust particles are negatively charged and there is electrostatic repulsion between the negatively charged SDBS. Since XT-100 is a non-ionic surfactant, there is no electrostatic adsorption, which can enhance the wettability between dust particles. When the active adsorption sites on the particle surface are occupied by XT-100 molecules, it is more conducive to polymer molecules the dust particles are
combined [13].

3.4. The influence of chemical coagulant of dust removal efficiency

3.4.1. The effect of chemical coagulant on dust removal efficiency
Different chemical coagulants have different coagulation effects on coal-fired power plant dust, so the dust removal efficiency is also different. During the experiment, other quantities are unchanged, and only change the type of chemical coagulant. The experimental results are shown in Table.1. It can be seen that the dust removal efficiency is improved after adding the chemical coagulant. Among them, after adding XTG, the removal efficiency is the highest, the highest is 97.98%. This is because after adding the chemical coagulant, the fine particle dust is condensed into large particle dust, it improves the dust collection efficiency of the wet electrostatic precipitator.

| Coagulation agent | H2O | PAM | PAC | CMC | SA | XTG |
|-------------------|-----|-----|-----|-----|----|-----|
| Collection efficiency (%) | 93.74 | 95.68 | 96.99 | 96.98 | 97.06 | 97.98 |

3.4.2. The influence of chemical coagulant concentration on removal efficiency
The different concentration of chemical coagulant has different effect on dust coagulation, therefore, it also affects the dust removal efficiency. On the same condition, when the XTG concentration is changed, and the experimental results are shown in Table.2. It can be seen that when the XTG concentration is 1.0×10⁻² g/L, the removal efficiency will be the largest, which can reach 97.98%.

| XTG concentration (×10⁻² g/L) | 0 | 0.1 | 0.5 | 1.0 | 1.5 |
|-------------------------------|---|-----|-----|-----|-----|
| Collection efficiency (%)     | 93.74 | 94.50 | 96.98 | 97.98 | 96.85 |

3.4.3. The influence of surfactants on dust removal efficiency
The types of surfactants have different effects on dust coagulation and will also affect the dust removal efficiency. With other conditions unchanged, SDBS, 1227, and XT-100 were added, and the results are shown in Table.3. After the surfactant is added, the removal efficiency is significantly greater than that without surfactant. Among the 3 surfactants added, 1227 has the highest removal efficiency, which reaches 98.80%. The analysis shows that the removal efficiency is the highest for the dust coagulation effect.
4. Conclusions
Under the same conditions, by changing the chemical coagulation type, concentration and surfactant type to carry out the dust removal experiment, the following conclusions can be drawn:

(1) When the chemical coagulant is not added, the median diameter of dust is 31.75 μm. After adding the chemical coagulant, the median diameter of XTG is 50.00 μm, SA is 44.85 μm, CMC is 42.52 μm, PAC is 39.08 μm, and PAM is 33.12 μm, it indicates that the chemical coagulant has a coagulation effect on the dust of coal-fired power plants, and the best effect is XTG.

(2) When the XTG concentration is 1.0×10⁻² g/L, the dust particle size is within the range of 1 μm<d<10 μm, and the content is the least, which is 7.32%.

(3) Adding surfactants can improve the dust removal efficiency. The best removal effect of 3 kinds of surfactants is 1227, and the removal efficiency can reach 98.80%.

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Table.3 The influence of surfactants on dust removal efficiency

| Surfactant   | H₂O   | SDBS  | XT-100 | 1227  |
|--------------|-------|-------|--------|-------|
| Collection efficiency (%) | 97.98 | 98.10 | 98.37  | 98.80 |
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