Study on PM$_{2.5}$ control of smelting smoke by electrostatic agglomeration

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Abstract. Fine particles emitted from nonferrous smelting furnaces contains a variety of heavy metals and oxidized condensates, which are characterized by complex composition and great harm. In this paper, an electrostatic agglomeration - electrostatic bag remover system was developed to improve the removal rate of PM$_{2.5}$ and heavy metals. Results showed that, the particles are charged and agglomerated after the electrostatic agglomeration process, which is more conducive to the later collection of particles by bag precipitators. The overall removal efficiency of the whole particle is dramatically increased.

1. Introduction
PM$_{2.5}$ emitted by nonferrous smelting furnaces is enriched with a variety of metallic elements, and is a significant contributor to Pb, As, Cd, Cr, Hg, Cu, Ni, Zn and other heavy metal pollutants in the air. It was found that heavy metals and their oxides were mainly concentrated in fine particles under 2.5$\mu$m or even 1$\mu$m [1-3]. When inhaled, these heavy metals can have varying effects on neurological function. The existing traditional dust removal equipment of metallurgical furnace is not ideal for PM$_{2.5}$ removal, and the single dust removal technology cannot meet the new standard requirements. Therefore, it is an urgent task to develop new dust removal technologies and equipment to improve the removal rate of PM$_{2.5}$ and heavy metals. Electrostatic agglomeration is one effective method to overcome the problem.

In this study, chemical properties and size distribution of lead smelting dust was analyzed, and agglomeration efficiency of fine particles in lead dust was tested using electrostatic agglomeration. The dust removal system is made up of trial-produced dust generator, tube type electrostatic agglomeration device and electrostatic bag remover. Particle size and concentration changes of dust and the removal efficiency of the device for fine particles were analyzed.

2. Particle size distribution
For the study of particle size and heavy metal content, stone filter membrane was used for sampling and blank experiment was conducted, the contents of four heavy metal elements, including Pb, As, Cu and Zn, were finally determined by ICP-MS and ICP-AES, and the content of heavy metals in particulate matter at grade level $\geq$9.0$\mu$m, 3.3-4.7$\mu$m, 0.4-0.7$\mu$m was determined.

The particle size distribution characteristics of heavy metals are shown in table 1. It can be seen that heavy metals such as Pb, As, Cu, etc. generally show a trend of higher enrichment degree with smaller particle size, and the content of Zn does not change much with particle size.
3. Experimental equipment
The experimental equipment consists of the following parts:

(1) Smoke simulation generating device
The device is modified by electric feeder, and the amount of dust transported is different at different speeds, so as to simulate the occurrence of smoke and dust at different concentrations.

(2) Electric coagulation system
The condenser is of cylindrical structure, with a length of 70cm and a diameter of 20cm. The corona wire is made of steel wire with a diameter of 1mm. There are two sets of power supply, one is high voltage DC power supply, the frequency is 50Hz, the rated output voltage is 50kV; The other set is high voltage frequency conversion AC power supply with rated output voltage of 50kV and rated output current of 200mA.

Fluent was used to simulate the movement track of dust, and the particle movement velocity was set at 8m/s. Before entering the bag dust collector, the movement track of dust in the condenser was shown in figure 1. In the coagulation section, particulate matter basically does not settle on the pipe due to gravity sedimentation, and it slightly settles after leaving the pipe. Therefore, the influence of particle size change caused by dust sedimentation can be ignored.

4. Experimental results
The removal efficiency of ultra-fine particles by the integrated dust removal equipment was investigated. The voltage applied by the coagulation unit was set as 25kV, 35kV and 45kV respectively, and the dust removal performance of the integrated device was investigated. It can be seen from figure 2, figure 3 and figure 4 that the removal efficiency of PM$_{1.1}$, PM$_{2.2}$, PM$_{3.3}$ and PM$_{10}$ all reach the peak value at 35kV, and the removal efficiency at AC voltage is higher than that at DC voltage.

| Particle size | Pb   | As   | Cu   | Zn   |
|---------------|------|------|------|------|
| ≥9.0μm       | 30.35| 0.42 | 7.64 | 12.68|
| 3.3-4.7μm    | 29.71| 0.42 | 4.56 | 13.7 |
| 0.4-0.7μm    | 35   | 3.75 | 45   | 12.5 |
According to Figure 2, under AC voltage, the initial removal efficiency of PM$_{1.1}$, PM$_{2.2}$ and PM$_{3.3}$ is 40%, 60% and 78% respectively, then increases to 70%, 74% and 86% respectively, and then decreases. Under the same conditions, the removal efficiency of PM$_{1.1}$, PM$_{2.2}$ and PM$_{3.3}$ increases to 51%, 68% and 84% respectively when DC voltage is applied, and then decreases.

According to Figure 4, when the voltage range is 0-45kv, the removal efficiency increases successively from the initial 98.5% to 99.9% and 99.3% and then decreases, which is consistent with the coagulation trend line of fine particles. Therefore, fine particulate matter coagulation promotes the efficiency of dust collection. The removal efficiency under AC voltage is higher than that of DC, which is also related to the higher coagulation efficiency of AC on fine particles. The particles are charged and agglomerated after the electrostatic agglomeration process, which is more conducive to the later collection of particles by bag precipitators. The overall removal efficiency of the whole particle is dramatically increased.
5. Conclusions
This paper designs a PM$_{2.5}$ electrocoagulation and pretreatment system, which is in series with the conventional dust collector, and studies the collaborative control technology of PM$_{2.5}$ and heavy metal pollutants in the flue gas of nonferrous smelting furnaces. The use of the new composite dust remover after optimization and transformation can significantly improve the removal rate of PM$_{2.5}$ dust particles and heavy metals in the fume of metallurgical kiln, and help to improve local air quality. The optimized new composite dust collector has excellent performance, high reliability, low energy consumption and low operation and maintenance cost.

References
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