Lead dust removal using electrostatic agglomeration

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Abstract. PM2.5 (particulate matter smaller than 2.5 microns) emitted from non-ferrous metal smelting is a significant contribution to variety of heavy metals in the atmosphere. Previous studies found that, Pb, as and its oxide is mainly concentrated in PM2.5, or even PM1.0, which is seriously harmful to human health. The concern about fine particle emissions created a new problem to develop new methods to improve fine particle removal efficiency. 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 removal efficiency of fine particles in lead dust was tested using AC electrostatic agglomeration.

1. Introduction
Among the PM2.5 emission sources, the smoke and dust from nonferrous smelting furnaces contains a variety of heavy metal particles and oxidized condensates, which are characterized by complex composition and great harm. With the improvement of pollutant emission standards, most smelting factories have added acid absorption and dust removal equipment, and the coarse particles are significantly reduced, while fine particles below PM2.5 level are the main contributions.

PM2.5 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 2.5μm or even 1μm [1, 2]. 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 PM2.5 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 PM2.5 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 flow field simulation was verified and analyzed by Fluent, and a reasonable design scheme was obtained. The electrostatic agglomeration system is made up of trial-produced dust generator, tube type electrostatic agglomeration device and AC variable-frequency power. A Thermo-Anderson sampler for particulate matter smaller than 10 microns was applied to analyze content of fine particles before and after agglomeration.
2. Properties of Lead Dust

Lead dust produced by lead smelting was collected from the dust hopper of the bag dust collector. Laser analyzer of particle size showed that PM10, PM2.5 and PM1.0 account for 60%, 13% and 0.47% of the total weight (Figure 1).

![Figure 1. Size distribution of collected lead dust](image)

Figure 1. Size distribution of collected lead dust

Mass fraction of concerned heavy metals in PM2.5 was analysed, shown in Table 1. Pb, As, Cu, Zn and Cd detected by ICP-MS and ICP-AES showed high mass fraction, highlighting the importance of PM2.5 control in lead smelting fumes. Phase analysis found that the Pb element mainly included PbSO4, PbS, PbO, and Pb.

| Table 1. Mass fraction of heavy metals in PM2.5 of lead dust |
|---------------------------------|-----------------|
| Metal  | Mass fraction (%) |
| Pb     | 30.35            |
| As     | 0.42             |
| Cu     | 7.64             |
| Zn     | 12.68            |
| Cd     | 0.062            |

3. Design of the electric coagulation system

Fluent is used to simulate and verify the flow field, and a reasonable design scheme is obtained. In order to simulate the trajectory of smoke and dust, a particle velocity of 8m/s is set up, and the dust trajectory in the circular condensation pipe is simulated by Fluent. Before dust enters the bag filter, the trajectory of dust is shown in Figure 2. and Figure 3. It can be seen that particulate matter does not settle on the pipeline due to gravity sedimentation in the coagulation section, and micro-sedimentation occurs after leaving the pipeline. Therefore, for the subsequent analysis of coagulation effect, the particle size change caused by dust sedimentation can be neglected.
4. Experimental Results

4.1. Influence of the Volt-Ampere Characteristics of HVDC Power Supply on the Coagulation Effect of Ultrafine Particles

At room temperature, the DC high voltage power was supplied. The charging voltage of HVDC increases step by step from 0 kV to 50 kV. The initial dust concentration is 6.0 g/m³, the fan frequency is 50 Hz, and the air volume is 800 m³/h. Under different parameters, the particle size of smoke and dust is measured by Malvern laser particle size analyzer.

The mass fraction of particulate matter in the range of 0-11.0μm decreases after DC high voltage coagulation, and the volume fraction of particulate matter with particle size larger than 11.0μm increases. Particulate matters with smaller particle size coagulates into larger particulate matters. Especially, for PM1.0, PM1.0-3.0 and PM3.0-11.0, the coagulation effect is obvious, and the mass fraction was reduced from 0.39%, 18.66% and 58.28% to 0.21%, 8.62% and 41.78% in a 42 kV, 0.3mA electrical condition.
4.2. Influence of the Volt-Ampere Characteristics of High Voltage AC Power Supply on the Coagulation Effect of Ultrafine Particles

At room temperature, the AC high voltage power was supplied. The initial dust concentration is 6.0 g/m³, the fan frequency is 50 Hz, and the air volume is 800 m³/h.

The mass fractions of PM1.1, PM2.1, and PM3.3 are shown in figure 4 below. When PM1.1 is at 25kV, the mass fraction reaches the lowest and the coagulation effect is the best. At 35kV, the mass fraction of PM2.1 and PM3.3 reached the lowest, and they decreased from 1.116% and 3.090% to 0.038% and 1.287% respectively. It can be seen that the coagulation efficiency of PM1.1, PM2.1 and PM3.3 is above 58%, and the coagulation efficiency of PM2.5 is also above 58%, which plays an important role in the emission control of PM2.5 in lead smelting dust.

It is found that the coagulation effect of high voltage alternating current on ultrafine particles is better than that of HVDC.

![Mass fractions of PM1.1, PM2.1 and PM3.3 under AC voltage](image)

**Figure 4.** Mass fractions of PM1.1, PM2.1 and PM3.3 under AC voltage

5. Conclusions

In this paper, removal efficiency of fine particles in lead dust was tested using electrostatic agglomeration. Results have shown that the application of electrical agglomeration as a pre-treatment method can significantly improve the removal efficiency of fine particulates and associated heavy metals in lead smelting fume. The coagulation effect of high voltage alternating current on ultrafine particles is better than that of HVDC.

Acknowledgments

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