The theory research and electric field simulation of the AHPC

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Abstract. Diameter of different corona electrode, distance of lines and distribution of the electric field of the porous dust collection plate of the AHPC electrostatic fabric filter were studied and analyzed on the basis of MATLAB PDE Toolbox. The simulation results of the AHPC electric-bag composite dust collector electrical fields show that when the corona polar diameter was 4 mm and distance between neighboring electrodes was 196 mm, the performance of the electric field was better. And the larger the aperture was, the higher the electric potential of the porous plate would be. Compared with the experimental research, it is simpler, visual and economical to use the MATLAB PDE to find the electric-field distribution of the electric-bag composite dust collector, it can provide theoretical basis for design and modification of corona wire diameter, line-spaces and precipitating plate aperture.

1. Introduction
In recent years, scholars at home and abroad have conducted lots of research work of the electric-bag dust collector [1]. The results show that electric-bag dust removal technology got the advantages of the electrostatic precipitator and the bag filter. Furthermore, new performance advantages will come into appearance when the advantages of the above two filters were put together. This made a complementary of the advantages of the dust removal come true, and has a good application prospect [2]. The research and development of the electric-bag composite will make an important contribution to precipitators in coal-fired power plants in China during the "energy conservation and emission reduction" environmental protection policy period.

The studies of this paper provided theoretical bases and the reference for the optimal design of the electric-bag composite precipitator and helped to improve its overall performance and dust removal efficiency and promote efficient filter design and application. It has a very important practical significance in reducing dust emission concentrations and atmospheric pollution.

2. The research of the AHPC theory

2.1. The AHPC

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The AHPC was designed by the Energy and Environmental Research Center of the University of North Dakota (“EERC” for short) in 1999, the overhead view is shown in figure 1. In the AHPC dust removal, porous plates are arranged on both sides of the filter bag, with alternating electrodes and filter bags.[3-4]

2.2. Mechanism of dust removal
As a new and effective dust collector, it owns the dust removal mechanisms and technics of electrostatic precipitator and bag filter (figure 2).

80%-90% of the amount of dust is collected when dust-containing gas flows through the ESP area, and then the remaining charged dust passes through the plate holes to the back filter bag by the electric field, and is collected by the filter bag to ensure a low concentration of dust emissions.

When dust is removed by the bag filters, there will be a backflow through the porous plate of the dust. Because there is a condensation of the dust collected on the surface of the filter bag, the size of the dust enlarged, the dust can be caught effectively by the collection plate in the electric field. And the probability that the dust will return to the filter bag decreased greatly by avoiding secondary adsorption of the filter bag. In the same way, dust which did not fall into the dust ash hopper may enter the filter area and be collected by the filter bag. Some shortcomings that might result in a decline of dust removal efficiency are
overcome. The dust removal efficiency of the AHPC is improved. The porous boards of AHPC have two functions apart from capturing charged dusts, and another important role is that it can protect the filter bag from damage of corona discharge. The equipment has a long-term and stable operation, the dust removal efficiency can be higher than 99.99%, and the resistance can maintain at 2000 Pa or even less.

The AHPC mainly uses pre-charged dust to increase the performance of bag filtration. The technology which combines the pre-charged dust technology and the bag filter can improve the dust removal efficiency, reduce the loss of pressure and make dust removal easier. The filter pressure is small mainly because of the coagulation of the charged dust and the charged dust layer structure on the surface of the filter bag. The analysis is shown in figure 3.

![Figure 3. The influence of charged dust to pressure loss.](image)

The charged dust layer structure on the surface of the filter bag is shown in figure 4. As shown in figure 4, the charged dust arrived the filter materials surface earlier repels the one arriving later, therefore, deposition on the surface of the filter bag forms a loose and uneven structure. This kind structure has good air permeability and great porosity. The uncharged dust on the surface of the filter bag is a close-grained flat structure (figure 5).

![Figure 4. deposition of charged dust](image)  ![Figure 5. deposition of uncharged dust](image)

3. Unit model of the AHPC

3.1 Model parameters of the bag filter unit

The four circular bags are used. The diameter is 130 mm and the length is 6 m with an area of 9.8 m². Filtering wind speed is 2.4 m min⁻¹; the dust capacity is 23.52 m³ min⁻¹.

3.2. The model parameters of electrostatic precipitation unit

When filtering wind speed is 2.4 m min⁻¹, the plate-to-cloth ratio (the ratio of porous plate dust collecting area and the filter bag area) should be 1.151, the filtering area is 9.8 m², so the effective area of the dust
collecting board is 11.28 m$^2$, the porous plate opening rate is 40%, and the dust collecting board length is 1.565 m.

1. The channel width of the electric field (the distance between two adjacent plates) is 300 mm.
2. The diameter of corona lines is 2 mm, 4 mm and 10 mm, respectively.
3. According to the corona line number, line spacing is determined. The Corona line numbers were 6, 7 and 8, and the corresponding line spacing is separately 224 mm, 196 mm and 174 mm.

The porous plate is 2 mm thick, and the open hole is round. According to the dust collecting effective area and the plate opening rate, the total area of holes is 7.52 m$^2$. The hole diameter are 25 mm, 51 mm and 64 mm. According to the geometry of the dust collecting board, we calculate the number of holes with different diameter and place the holes equably.

The final geometry arrangement and the relevant parameters of the 2D model are shown in figure 6. The diameter of the corona line is 4 mm, line spacing is 196 mm, and aperture is 51 mm.

![Figure 6. The 2D model.](image)

4. Simulation of the AHPC electric field

Due to the structure complex of AHPC and the strong nonlinear process discharge of the corona, it is very difficult to obtain the analytical solution of the electric field. The PDE toolbox is applied to simulate the simplified 2D model of the electric field distribution of the AHPC and to analyze the theory. Compared with the electric field performance in different electrode structure configurations, certain bases and the references are provided to optimize and improve the AHPC.

4.1. Profile of PDE toolbox

PDE toolbox is a set of tools which is used to solve a partial differential equation based on MATLAB. Its core is a program which solves partial differential equations with the edge boundaries defined by the finite element method. The PDE toolbox has some professional communication modes, such as the electrostatic field, the static magnetic field and the electromagnetic field. The powerful numerical calculation functions made it is convenient for to solve the electric field distribution, and the result is graphic, intuitive audio-visual [5-7].

4.2. Simulation of the AHPC

The simulation models are built based on certain assumptions. The simulation process: build the calculation model in the GUI of the PDE toolbox, as shown in figure 7, choose electrostatics mode, set the
dielectric constant to be 1, charge density of the body to be 0, and then set the boundary conditions, discrete grid, drawing solution. The simulation results is shown with graphics. 60 kV negative voltage is added as the boundary conditions of the electrode surface when the dust collector operates normally. The dust collector wall, the filter bag and orifice is grounded, and the potential of them is zero.

![Figure 7. The simulation model.](image)

4.3. The simulation result analysis

In the AHPC two-dimensional model, the electric field intensity of the negative corona discharge under different electrode parameters is derived from the isoline map of the field, as listed in table 1.

| Corona line diameter (mm) | Electrode distance (mm) | Aperture (mm) | Field Biggest (kV cm⁻¹) |
|--------------------------|-------------------------|---------------|-------------------------|
| 2                        | 196                     | 51            | 143                     |
| 4                        | 196                     | 51            | 75                      |
| 10                       | 196                     | 51            | 27                      |
| 4                        | 174                     | 51            | 70                      |
| 4                        | 196                     | 51            | 75                      |
| 4                        | 224                     | 51            | 68                      |
| 4                        | 196                     | 25            | 69                      |
| 4                        | 196                     | 64            | 71                      |

(1) The influence of corona polar diameter on electric field distribution

When the corona line distance is 196 mm, pore diameter is 51 mm, with the increase of corona wire diameter, the electric field strength value near the electrode reduce and then the corona electrode diameter is smaller, and the corona discharge ability is stronger.

According to the Peek formula, the varying electric field strength of the electrode can be calculated [8]. The values under the different corona electrode diameters are calculated in table 2, and the electric field strength of the corona discharge is also listed.

It is known that the largest field strength of the corona discharge is less than the electric field intensity when the corona line is 10 mm in diameter, thus it cannot produce normal corona discharge. From the electric field non-uniform coefficient formula, it is observed that the average of the field is
determined; the uneven electric field non-uniform coefficient is greater when the maximum value of the field is higher. In order to improve the breakdown voltage, we must minimize the non-uniform extent of the electric field. The maximum value of electric field strength is not ‘the bigger the better’, when achieve the varying electric field strength. Through analysis, a corona line of 4 mm in diameter is more appropriate under the model parameters, and has enough mechanical strength.

Table 2. The electric field strength under different diameter of the corona wire.

| Corona Electrode Diameter (mm) | 2   | 4   | 10  |
|-------------------------------|-----|-----|-----|
| Electric Field Strength (kV cm⁻¹) | 143 | 75  | 27  |
| Circulating Electric Intensity (kV cm⁻¹) | 48  | 42  | 36  |

(a) Aperture is 25 mm  
(b) Aperture is 51 mm  
(c) 64 mm (near the discharge)  
(d) 64 mm (near the filter bag)  
(e) no porous plate

Figure 8. The partial enlarged view of potential isoline (V).

(2) The influence of the electrode distance on electric field distribution

When the corona wire diameter is 4 mm and the aperture is 51 mm, with the increase of corona wire distance, the largest electric field strength increases, and then decreases, but with little change. The maximum values of electric field strength are higher than the circulating electric strength for 42 kV cm⁻¹. When the electrode distance is small, the electric field of the corona wire mutually influences, restrains
and weakens the corona electric field, the corona current reduced. It is a kind of phenomenon of electric field shield, some attention should be paid to designing the electric dust removal unit. Along with the increase of corona wire distance, the electric field strength value increases a little, and then drops. The wire distance is too many, even though each corona wire can discharge fully, and the current value of the single wire is larger, but the corona wires reduce in the electric field causing the total corona current to reduce. Therefore, there exists an optimal wire distance to produce the maximum corona current. If corona wire distance is less than or greater than the best value, the corona current will be reduced.

(3) The influence of the aperture on electric field distribution

① the relationship between the aperture of the dust collecting plate and the greatest electric field strength

When the corona polar diameter is 4 mm, and the distance between corona wires is 196 mm, with pore diameter in the multi-hole plate changes, the change of the greatest corona field is not obvious. Visibly, the size of the aperture has little impact on corona discharge.

② the influence of the aperture on electric potential distribution

Pore plate whose orifice aperture is 25 mm, 51 mm or 64 mm are distributed on both sides of the bag, the electric potential distribution of the bags without perforated plate around the bag, see in figure 8. It can be seen from figure 8 that the potential of the filter bag in the protection of the perforated plate is very low, what’s more, it is much lower than the one without the perforated plate. It is indicated that the smaller the hole’s size is, the lower of electric potential of the perforated plate is. The simulation results show that even if the hole’s diameter takes 64 mm of the maximum one, the filter bag can also be protected well from corona discharge damage.

5. Conclusions

The electric-bag composite dust collector has the advantages of the electric and bag dust collector. It can make a reasonable assignment of dust loading during dedusting and deashing. Compared with the experimental research and to stimulate with a computer program, it is simpler, visual and economical to use the MATLAB PDE to find the electric-field distribution of the electric-bag composite dust collector, it can provide theory basis for the choices of corona wire diameter, line-spaces and precipitating plate aperture of the design and modification.

Acknowledgments

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