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LABORATORY RESEARCH ON COLLECTION OF PARTICLES REENTRANIED FROM CORONA ELECTRODE

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ABSTRACT

At the exit of electrostatic precipitator, among the escaped particles there have not only neutralized particles, but also particles that remaining negative and positive charges. Sometimes positively charged particles can account for 30%~50% of the total particles escaped. They are formed probably from the reentrainment by corona electrode rapping or from back corona effects. In view of this phenomena, for strengthen the corona electrode capability of capturing positively charged particles; new types of corona electrodes were investigated. It has multi-function of corona discharge, reducing back corona, prevent reentrainment and collect the positively charged particles.

Different types and geometries of corona electrodes were proposed; all of them were featured to add a channel shaped wind buffer, which has the same voltage with the corona wire and located between subsequent corona wires. These buffers can reduce gas flow scouring reentrainments, collect positively charged particles and restrain back corona by electrostatic shielding effect. Bench scale laboratory tests were made to explore their discharging characteristics, current density distributions, etc. Two- dimension flow mathematics models were set up and boundary conditions were confirmed. Using k-ε equation, the pure air turbulent flow fields of corona electrodes with and without wind buffers were studied.

Tests shown the shielding benefits of both reducing the gas flow scouring and back corona were more remarkable when the distance between buffer and corona wire became closer. But if too small, the over reducing of corona discharge and breakdown voltage will give reverse effects. By optimizing this distance, a steady, high performance operation can be gotten. Laboratory experiments give the recommended distance was 150mm and the recommended buffer width was 60mm.Pilot and industrial tests of likely shielded corona systems also revealed the same beneficial effects.

INTRODUCTION

Based on some references, there are numbers of positive charges and neutralized particles at the exit of large-scale electrostatic precipitator (ESP). Sometimes the particles with positive charges can occupy 30% ~ 50% of total particles, which are occurred probably from the reentrainment by corona electrode rapping or from back corona effects.[1] The collection efficiency would improve greatly if those particles above are collected. The hardcore of ESP is the two systems: anode system and cathode system. The cathode system establishes the high intensity field with anode system together, it can provide the free electrons or negative ions for particles by corona discharge, and synchronously it has function of collecting particles. However, it doesn't attach importance as its function of collection. In this paper, the positive ions brought by cathode corona discharge and the particles with positive charges of cathode are taken full advantage, and the cathode corona discharge and its collection function are researched. Based on those above, the methods improving the collection ability of cathodes are studied as follows [2,3,4].

- Decreasing the discharge intensity in order to conquer or weaken the back corona.
- Preventing or weakening the second blowing dust of cathode by disposing the windbreak plates on the cathodes of ESP.
- Adding the collection area of cathodes properly to improve the potential of dust collection of cathode.

In this paper, several reformative methods to cathode system are researched.

EXPERIMENT ON THE CHARACTERISTIC OF DISCHARGE

Based on the theory of collected particles and the theory that second voltage is high and synchronously second current is low, there is a method to collect the particles with positive charges effectively by adding the support area of cathode wires and installing the windbreaks. This method can prevent the second blowing dust of cathode and the aggradations amount on the prick electrode and improve the collection function of cathode. The Volt-ampere characteristic of wires and windbreak plates are studied in experiments by designing different wires and plates.

Figure1 shows the ESP test-bed. It is to study the discharge characteristic in experiments and it is to simulate a alleyway of ESP. For convenience, the collecting electrode of this tester is installed horizontally; the other plate is taken out.

The collecting electrode adopted in experiments is flat plate, and the cathode wires can be RS pipe and spike electrode. RS rectangle and spike electrode, and flat plate with 20mm saw-teeth. Besides, the back corona is simulated in the experiment, and the simulation of ash load with high specific resistivity is the organic glass-plate with 10^{14}O•cm. The test of current density for the plate adopts gridding of micro-area current signal mensuration. Figure2 and Figure3 show the structure of cathode wires and the matching forms between cathode wires and the windbreaks[5,6,7].

Table2 to Table4 shows that the breakdown voltages of different wires are different influence to the width of the windbreak plates. To RS pipe and spike electrode, the influence occurs when the width of the windbreak plate reaches 100mm. To RS rectangle and spike electrode, the influence occurs when the width of the windbreak plate reaches 76mm. To flat plate with 20mm sawtoothes, the influence occurs when the width of the windbreak-plate reaches 66mm. So the conclusion can be drawn out that the cathode windbreak plate influences greatly to the cathode wires when weak discharge and high breakdown voltage. With the increase of the windbreak width, the breakdown voltage has the decrease trend in spite of any wire, and this trend is unobvious until the width of windbreak reaches a certain data. So the windbreak plates with adaptive width are selected. They need hardly influence the breakdown voltage. They need prevent or weaken the second blowing dust, and synchronously improve the collection and total capability of ESP.

Volt-ampere characteristic

When the windbreak plate is installed on the ESP model, it may influence the corona discharge of wires and the volt-ampere characteristic of cathode wires may change because of the same potential between windbreak and cathode wires. Figure4 to Figure6 show the volt-ampere characteristic installed the windbreak plate with 60mm width.

RESULTS AND ANALYSIS

Starting Corona and Breakdown Voltage

Under the condition of room temperature and air medium, the starting corona and the breakdown voltage of three kinds of cathode wires in Figure2 are tested, and Table1 shows the results.

For conquering or weakening the second blowing dust, every cathode wire can be installed a cathode windbreak plate just on the current direction, and the center of plate is as the same horizontal line with the center of cathode wire in order to prevent the current to scour the wire. And the space between different electrodes will diminish so that the breakdown voltages of ESP change if the windbreak plate is installed. From Table2 to Table4 show the breakdown voltages under different conditions.

Table1: The breakdown voltage of different wires(2b=250mm, 2c=500mm)

Wire type	RS pipe and spike electrode	RS rectangle and spike electrode	Flat plate with 20mm sawtooths
Unload Up/kV	94	106	110
Load Up/kV	55	61	67
U_0/kV	10	16	18

Table 2: The breakdown voltage of RS pipe and spike electrode installed windbreak plate (2b=250mm, 2c=500mm)

Width of windbreak-plate (mm)	0	90	100	110
Unload Up/kV	94	94.5	91	86.5
Load Up/kV	55	54	51	48

Table 3: The breakdown voltage of RS rectangle and spike electrode installed windbreak plate (2b=250mm, 2c=500mm)

Width of windbreak-plate (mm)	0	56	66	76	86	96
Unload Up/kV	106	106	104	102	99	92
Load Up/kV	61	60	59	58	53	47

Table 4: The breakdown voltage of flat plate with 20mm sawtoothes installed windbreak plate (2b= 250mm, 2c=500mm)

Width of windbreak plate (mm)	0	36	46	56	66	80	90
Unload Up/kV	110	109	108	106	105	101	92
Load Up/kV	67	67	66	65	63	56	51

From Figure4 to Figure6, when the windbreak plate is installed, it may bring electrostatic shielding function to the cathode wires and the discharge intensity of cathode wires may be restrained because of the same voltage between windbreak and cathode wires. And synchronously the corona current will be decrease. The distance between plate and wire is closer, the influence and the decrease degree of current is greater.

Distribution of Plate's Current Density

The distance between two plates in the experiments is 250mm, the width of windbreak plate is 60mm, and the test voltage is 45kV. Table5 shows the calculated relative average difference square root s and max relative error $?_{max}$ to different electrode matching models.

From Table5, when the cathode is installed the windbreak plate, the distribution of anode's current density is incongruous. Under the same conditions, the plate's current density of RS pipe and spike electrode is more uniform than RS rectangle and spike electrode and flat plate with sawtoothes, and RS rectangle and spike electrode is more uniform than flat plate with sawtoothes. However, the windbreak plate can restrain the corona current effectively, and the corona current is also lower than the current without windbreak even if the discharge is the most drastic. So it's benefit to restrain the back corona by adjusting the distance between the windbreak and the cathode wires.

Adaptive electrode matching can make particle charge, sedimentate, utilize the plate area on the max degree, and occur the second blowing dust on the min degree. Field state can select which kind of wires is better or not.

Table 5: Distribution of plate's current density

distance / result / model	Without windbreak		250mm		200mm		150mm		100mm	
	s	?max	s	?max	s	?max	s	?max	s	?max
RS pipe and spike electrode	0.66	1.87	0.68	1.91	0.68	2.03	0.73	2.13	0.76	2.28
RS rectangle and spike electrode	0.70	2.31	0.73	2.48	0.80	2.58	0.90	2.94	0.92	3.02
Flat plate with sawtoothes	0.84	2.53	0.87	2.54	0.88	2.65	0.94	2.95	0.98	3.14

CALCULATION AND ANALYSIS ON FLOW FIELD

Flow field of ESP was simulated using two-dimensional mathematics models of two dimensions k-e equations. Visible Difference Format was chosen, and SIMPLE arithmetic in the FLUENT program is applied. Set up two-dimensional flow field mathematics model for ESP, and synchronously confirm boundary and initial conditions. Using with adding the windbreak plate or without this plate. The distribution of flow field in one alleyway of ESP was evaluated. Figure7 shows the flow fields of different distances between windbreak plate and cathode as shown figures as follows. The width of windbreak plate was 6cm, the length of sidepiece was 2.5cm. The cathode was RS pipe and spike electrode.

For knowing how influence the windbreak to the flow field inner the alleyway of ESP, the conditions of room temperature and air flow are studied. And the parameters about alleyway are as follows.

The flow velocity for entrance gas	1.0m/s
Gas temperature	room temperature(25?)
Pressure of inlet	101325Pa
Width of alleyway	0.4m
Air dynamic viscosity inner flow field	1.79×10^{-6} m^2/s
Length of calculated region	2m
Width of windbreak	6cm

The results show in Figures 8,9and 10.

The curves of gas velocity with x axial are shown in Figures 11, 12 and 13.

From Figure8 to Figure13, there are two reverse eddies at the peristome of windbreak, and the gas velocity between two side-plates can even reach 1.1m/s while the velocities of other regions are congruous and the velocity difference of two eddies is unobvious.

The gas velocity is decreased gradually from the windbreak to the cathode wire, and the gas velocity is increased from 0m/s to the peak value while not reach 1m/s (the velocity of the main gas fluid), and then the velocity is decreased 0m/s again. With the increase of the distance between the windbreak and the cathode wires, the peak value of gas flow is increased gradually. That is shown that the thinner the distance between windbreak and cathode wire is, the better the windproof effect is. However the distance is not thin enough to influence the breakdown.

CONCLUSION

- The windbreak plate has a certain influence to the breakdown voltage of different pole of ESP. Among electrodes used in the experiment, when the width is 60mm, the windbreak plate does not influence the breakdown voltage with different corona wires.
- The cathode discharging capability was weakened by the influence of windbreak plate which has the same voltage to cathode. The influence is greater when the distance between windbreak and corona wire becomes closer. Considering the discharging experimentations and theory calculations, the recommended width is 60mm.
- The distribution of current density on the positive electrode becomes dissymmetrical after installing the windbreak plate. But the windbreak plate can suppress corona current effectively on a great degree. So the corona current may adapt work condition in a large scale to restrain back corona though adjusting the distance between plate and corona wires.
- The cathode windbreak plate has the function to prevent and reduce the airflow velocity. The smaller the distance between corona wire and plate is, the better the effect of windbreak is. But it will influence the discharging intensity and breakdown voltage between negative discharge electrode and the grounded collecting electrode if the distance is too small. So the recommended distance is 150mm.
- The device installed windbreak plate change the electrostatic precipitator similar to two-stage for high driving velocity and high collection efficiency.

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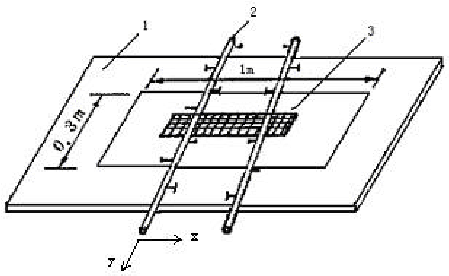
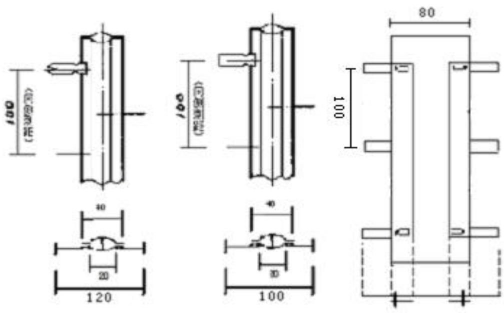


Figure 1: The ESP test-bed for discharge characteristic
1-collection electrode 2-cathode wire
3-little sheet copper



(a) (b) (c)

Figure 2: The parameters of cathode wires
a-RS pipe and spike electrode
b- RS rectangle and spike electrode
c-flat plate with saw teeth

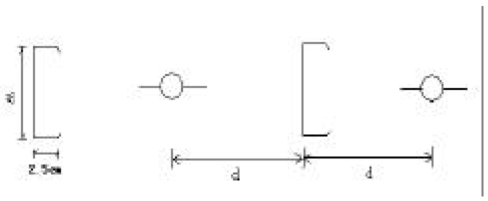


Figure 3: The disposal of cathode wires

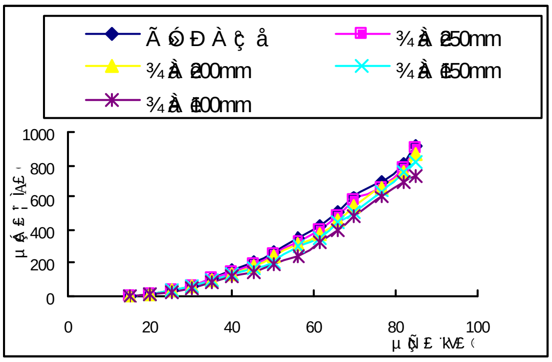


Figure 4: The volt-ampere characteristic of RS RS pipe and spike electrode installed the windbreak plate

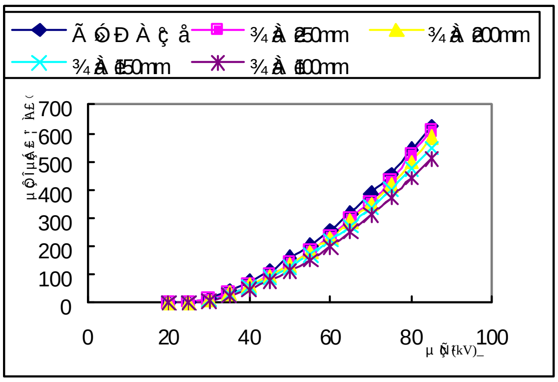


Figure 5: The volt-ampere characteristic of RS rectangle and spike electrode installed the windbreak plate

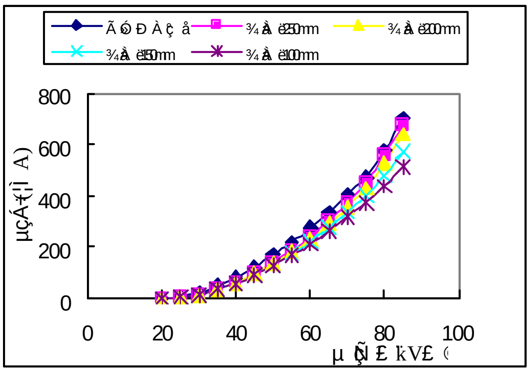


Figure 6: The volt-ampere characteristic of flat plate with 20mm sawtoothes installed the windbreak plate

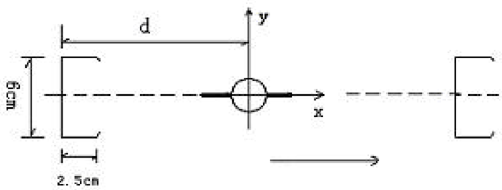


Figure 7: Figure on flow field calculation

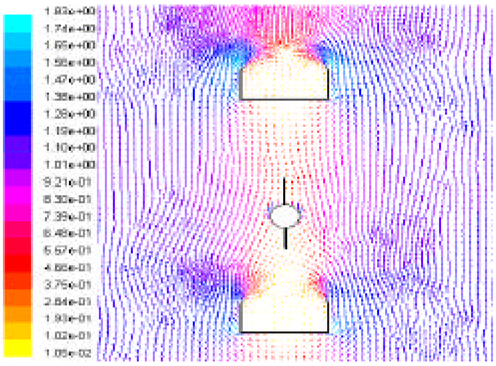


Figure 8: The velocity vector in flow field at 10cm distance

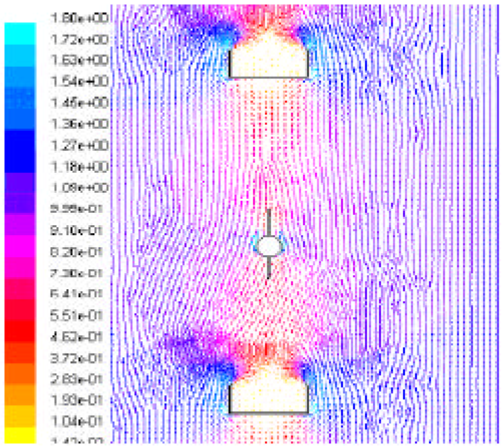


Figure 9: The velocity vector in flow field at 15cm distance

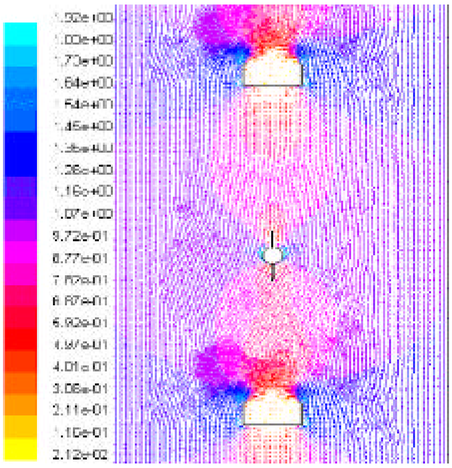


Figure10: The velocity vector in flow field at 20cm distance

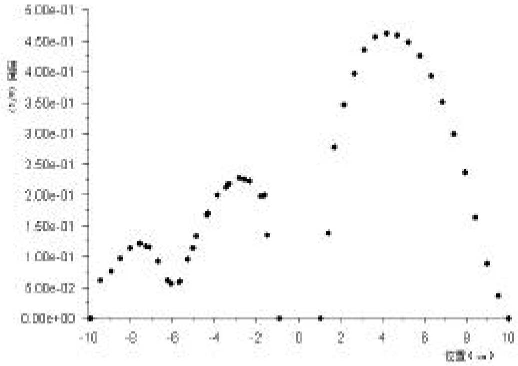


Figure 11: The curve in flow field at 10cm distance

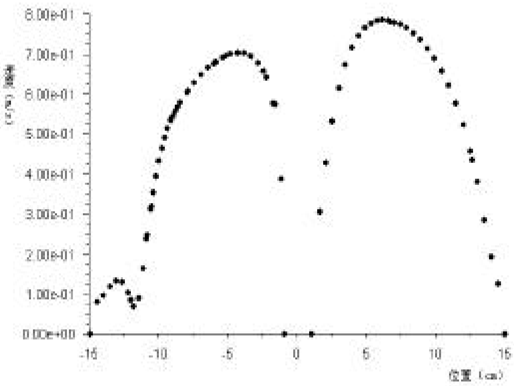


Figure12: The curve in flow field at 15cm distance

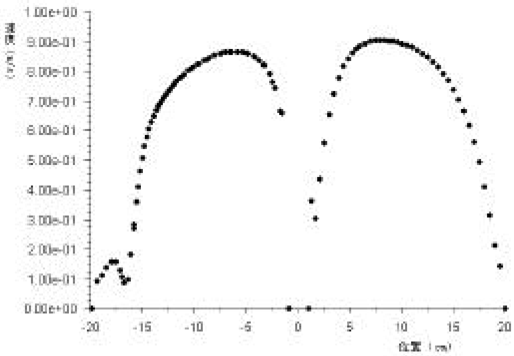


Figure13: The curve in flow field at 20cm distance