V-I Characteristic Principle of Electrostatic Precipitator

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Abstract: Based on the systematic analysis of the V-I characteristic of 384 group typical experimented electrodes-arrangements with the same 480 C plate collection electrode but various discharge electrode type, width of the cross channel, wire-wire spacing and design of the tri-electrode, this paper puts forward that V-I characteristic curve of common wire-plate type electrostatic precipitator can be expressed as $I=aV^b$ model and provide the corresponding value of a, b. The results indicate that R-square is less than 0.5%.

Keywords: Electrostatic precipitator, V-I character, Function

1 INTRODUCTION

V-I character is one of the most important factors affecting collection efficiency, while electrodes are the key component of ESP. Reasonable electrodes-arrangement is the precondition for gaining higher collection efficiency[5]. For ESP retrofitting, knowing about V-I characteristics of original electrode arrangements and comparing them with that of new ones are the first work for accurately enhancing collection efficiency. With the development of electrostatic precipitation technology, new type electrodes with different prickle spaces, shapes and dimensions are constantly emerging. How to select and design this key component and make full use of the equipment's functions has come into being an urgent work [1,3]. However at present, only several particulars of them selected for a specific project have been compared and analyzed, total electrode arrangements are not completely deeply and systematically studied together. So the urgent work is not really solved.

Based on V-I characteristic experiments, V-I characteristics of most typical electrode arrangements were analyzed, and the analysis results may be used as technical or theoretical supports for new-building, expanding and rebuilding of ESP.

2 EXPERIMENT SETS

This experiment system consists of high voltage power source, experimental instruments and testing platform (Fig. 1). High Voltage Power Source(HVPS) consists of voltage transformer and control cabinet, while experimental instruments are High Voltage Electrostatic Voltmeter (HVEV), milli-amperemeter and micro-amperemeter, see as Table 1.

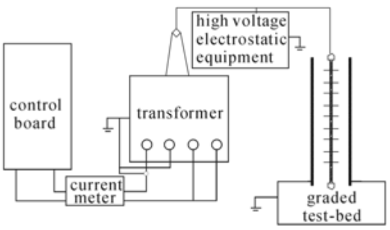

Fig. 1 Schematic of experiment system

Table 1 Specifications and patterns of experimental instruments

Tag	Type	Range
HVPS	GJX-10/100MC	100 kV/10 mA
HVEV	Q4-V	0–100 kV
milli-amperemeter	C46	0–500 μA
micro-amperemeter	C21	0–10/20 mA

Testing platform simulates a channel in industrial ESP. Discharge electrodes and collection plates of the channel with 2 m long (installing length of four 480 C type plates) are all framed structures in order to be easily changed. Collection plates are 1.2 m high, discharge electrode 1m high, channel width range is 250 mm-800 mm, space between discharge electrodes is continuously adjustable.

3 EXPERIMENT CONTENT

Four types of discharge electrodes such as fishbone wire 100 type (FW100, prickle length 100 mm), di-prickle wire (F2), quadri-prickle wire (F4) and octa-prickle wire (F8) etc. were selected as negative electrodes, while 480C as positive plate. One channel whose width is 350mm, 400 mm, 500 mm, 550 mm or 600 mm etc has four positive plates and 3, 4, 7 or 8 negative electrodes. So that 96 type electrode- arrangements can be formed and experimented (see as Fig. 2), and V-I characteristics of them are also analyzed.

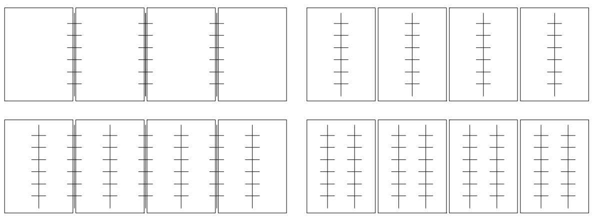

Fig. 2 Electrode-arrangements without auxiliary electrode

Otherwise, electrode-arrangements with auxiliary electrode (see Fig. 3 to Fig. 6) are tested and compared with above-mentioned electrode arrangements. Wide real lines in Fig. 3 are φ25 mm Tube-type auxiliary electrodes (connecting with discharging electrodes), which are placed in the middle of two discharge electrodes, center distance between auxiliary electrodes is 35 mm.

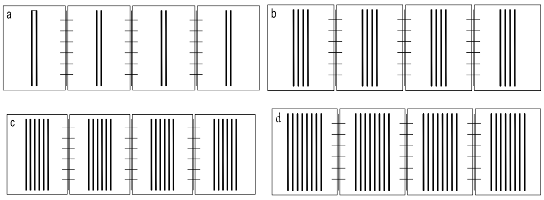

Fig. 3 Electrode-arrangements with 3 discharge electrodes and 8 auxiliary electrodes (a), 16 auxiliary electrodes (b), 24 auxiliary electrodes (c) and 32 auxiliary electrodes (d)

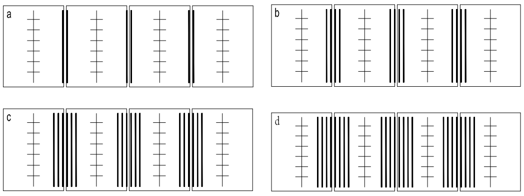

Fig. 4 Electrode-arrangements with 4 discharge electrodes and 6 auxiliary electrodes (a), 12 auxiliary electrodes (b), 18 auxiliary electrodes (c) and 24 auxiliary electrodes (d)

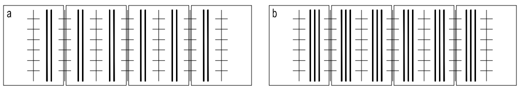

Fig. 4 Electrode-arrangements with 7 discharge electrodes and 12 auxiliary electrodes (a), 18 auxiliary electrodes (b)

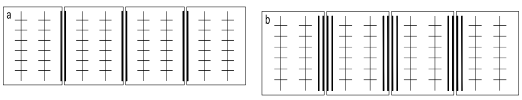

Fig. 6 Electrode-arrangements with 8 discharge electrodes and 6 auxiliary electrodes (a), 12 auxiliary electrodes (b)

EXPERIMENT RESULTS

As second current and second voltage reflecting running performance of ESP, V-I characteristic curve is used to analyze ESP operating conditions in order to find out the major influences on ESP collection efficiency and give references for management and maintenance[4,6]. So that V-I characteristic is considered as a major criterion for performance of electrode-arrangements. A super electrode-arrangement should have low discharge inception voltage, high spark voltage and larger discharge current[2].

All experimental results suggest that discharge inception voltages of most electrode arrangements are below 10 kV. and discharge inception voltages of wider channels are higher than that of more narrow channels, while discharge inception voltages of electrode arrangements with F8 wire are also higher than that of the others. Breakdown voltages of all the electrode arrangements are more than 80 kV.

As all V-I characteristic curves are similar to power function curve, experiment data could be fitted into $I=aV^b$ model by using Origin software. See as Fig. 7, the R-square is 0.99955.

Because of paper limit, only V-I characteristic fitting parameters of electrode arrangements with channel width 500mm are showed out in Table 2. R-squares of others are all above 99.5%. So that V-I characteristic fitting curves are authentic.

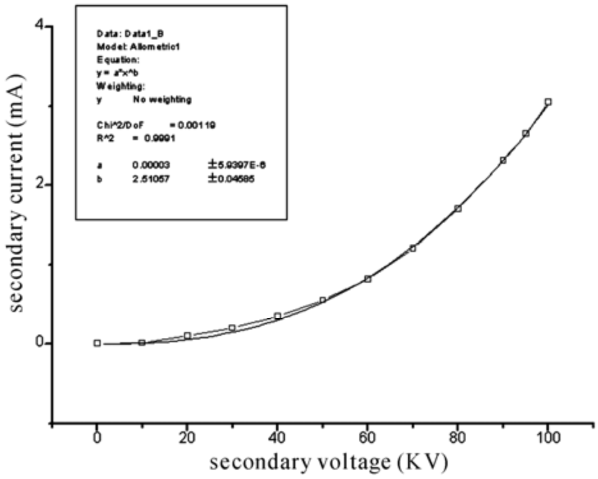

Fig. 7 Fitting curve of V-I characteristic experiment data

Table 2 Fitting parameters of V-I characteristic experiments data

Channel width (mm)	Electrode number	Electrode type	Auxiliary electrode number	*a*	*b*	R2
500	3	FW100	0	0.00002	2.56893	0.99634
500	3	FW100	32	0.00002	2.44573	0.99529
500	3	FW100	24	0.00002	2.46646	0.99757
500	3	FW100	16	0.00002	2.45278	0.99877
500	3	FW100	8	0.00003	2.43326	0.99832
500	4	FW100	0	0.00003	2.46147	0.99882
500	4	FW100	24	9.92E-6	2.63073	0.99779
500	4	FW100	18	9.16E-6	2.68237	0.99704
500	4	FW100	12	9.86E-6	2.67952	0.99571
500	4	FW100	6	0.00002	2.57268	0.99762
500	7	FW100	0	0.00004	2.46922	0.99955
500	7	FW100	18	4.34E-6	2.81636	0.9963

500	7	FW100	12	0.00001	2.66452	0.99883
500	8	FW100	0	0.00003	2.52566	0.9993
500	8	FW100	12	8.27E-6	2.73780	0.99962
500	8	FW100	6	0.00002	2.54303	0.99926
500	3	F2	0	0.00002	2.56893	0.99634
500	3	F2	32	0.00001	2.52038	0.99612
500	3	F2	24	0.00003	2.40603	0.99784
500	3	F2	16	0.00003	2.42019	0.99882
500	3	F2	8	0.00007	2.24381	0.99873
500	4	F2	0	0.00006	2.37365	0.99917
500	4	F2	24	0.00003	2.43102	0.99969
500	4	F2	18	0.00004	2.38541	0.99619
500	4	F2	12	0.00004	2.42525	0.99849
500	4	F2	6	0.00009	2.24437	0.99912
500	7	F2	0	0.00009	2.31043	0.99943
500	7	F2	18	0.00001	2.60660	0.99797
500	7	F2	12	0.00004	2.40935	0.99936
500	8	F2	0	0.00008	2.33226	0.99907
500	8	F2	12	0.00003	2.50250	0.99947
500	8	F2	6	0.00004	2.43688	0.99955
500	3	F4	0	0.00003	2.51057	0.9991
500	3	F4	32	5.21E-6	2.76216	0.99684
500	3	F4	24	0.00001	2.59921	0.99764
500	3	F4	16	0.00004	2.36713	0.99766
500	3	F4	8	0.00003	2.44282	0.99799
500	4	F4	0	0.00005	2.40010	0.99948
500	4	F4	24	0.00001	2.59807	0.99836
500	4	F4	18	0.00003	2.48424	0.99898
500	4	F4	12	0.00003	2.49266	0.99929
500	4	F4	6	0.00003	2.46714	0.99895
500	7	F4	0	0.00004	2.47840	0.99974
500	7	F4	18	7.74E-6	2.7550	0.99794
500	7	F4	12	0.00001	2.71152	0.99884
500	8	F4	0	0.00005	2.46543	0.99992
500	8	F4	12	0.00001	2.71535	0.9975
500	8	F4	6	0.00006	2.37049	0.99913
500	3	F8	0	0.00004	2.43862	0.99799
500	3	F8	24	6.94E-6	2.72689	0.99874
500	3	F8	16	0.00001	2.60423	0.99767
500	3	F8	8	0.00003	2.44084	0.99926
500	4	F8	0	0.00004	2.49919	0.99953
500	4	F8	18	0.00001	2.62565	0.99899
500	4	F8	12	0.00002	2.53963	0.99931
500	4	F8	6	0.00003	2.50694	0.99939

The significances of curve fitting for V-I characteristic data are:

(1) From curve fitting, V-I characteristics of different electrode arrangements are comprehended and wholly grasped, so that ESP mechanisms could be studied in a deep way by mathematical methods.

(2) Electrode arrangements could be directly compared with each other and selected by fitting functions. In this way, repetitiveness experiments are avoided and collection efficiency is enhanced.

Connecting with operating data in industrial working conditions, the database which is formed by curve fitting data of unload V-I characteristic experiments could supply detailed information for choosing electrode arrangements.

(3) Calculating unknown second current:

In industrial working conditions, when channel width between 200 mm and 300 mm working voltage is 60 kV-70 kV, while channel width between 400 mm and 1000 mm working voltage is 80 kV-200 kV[6]. if the max voltage of experimental power source is only 100 kV, so that unknown second currents to 100 kV-200 kV could be calculated by curve fitting functions.

4 CONCLUSIONS

This paper studied V-I characteristics of 384 group electrode arrangements with 480C type collection plate. V-I characteristic curves of these electrode arrangements conform to $I=aV^b$ model, parameters a and b were calculated out, repetitiveness experiments could be avoided and ESP electric field design should be facilitated.

Of course, besides V-I characteristic many other synthetical factors must be taken into account in ESP electric field design, such as physico-chemical properties of dust etc[7].

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