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Particle precipitation efficiency in an electrostatic precipitator

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Abstract

In this paper, results of the measurements of the size distribution of seed particles after their precipitation in a wire-plate-type ESP with seven wire electrodes are presented. The cigarette smoke was used as a source of seed particles. The particles of sizes from 0.5 to 8 μm were counted in the 0.5 μm-wide ranges at the ESP outlet using a particle size-meter of the laser light reflection type. The particle precipitation efficiency for each size fraction was determined for various primary flow velocities at positive and negative voltage polarity. Due to the size-meter measuring range limited to the particles larger than 0.5 μm, the present measurements do not show the precipitation of the particles of sizes smaller than 0.5 μm.

Keywords: Dust particles precipitation; ESP; Particle collection efficiency

1. Introduction

Recently, a special environmental concern is directed towards controlling the emission of micron and submicron particles in electrostatic precipitators (ESPs), which operate with high overall efficiency and are not effective in removing of fine particles [1]. Many fine particles of size 1 μm or less contain toxic trace elements such as lead, mercury, arsenic, zinc and others.

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The motion and precipitation of particles in the duct of an ESP depend on the particle properties, electric field, space charge and gas flow field. However, it is not yet clear whether these turbulent flow patterns enhance or deteriorate fine particle precipitation. To elucidate the influence of the flow disturbances generated mainly by electrical forces, more experimental investigations are needed on the precipitation of particles in ESPs.

In this paper, results of the measurements of the size distribution of the seed particles (after precipitation process) in a wire-to-plate-type ESP model with seven wire electrodes are presented. This investigation is expected to be helpful in elucidating the efficiency of the removal of fine particles in ESPs.

2. Experimental set-up

The experimental set-up consisted of an ESP model, high-voltage supply, working gas supply and particle size-meter.

The ESP model was a transparent plane-parallel acrylic duct, 160 cm long, 20 cm wide and 10 cm high. The outlet and inlet of ESP model were connected by a tight duct, forming a close flow loop. A fan, driving the flow, was mounted in the duct. In the middle of the ESP model, seven stainless-steel wire electrodes (diameter of 0.1 cm, length of 20 cm, 10 cm apart from each other) were mounted in the acrylic side-walls, parallel to the opposite-placed stainless-steel plate collecting electrodes. The distance between the collecting electrodes (110 cm long and 20 cm wide) was 10 cm. The voltage was supplied to each wire through a 10 MΩ resistor. The operating voltage, either negative or positive, was changed up to 32 kV. Air seeded with cigarette smoke (containing particles of sizes from submicron to several micrometers), was blown along the ESP duct (a primary flow). The average velocity of primary flow was either 0.2 or 0.8 m/s (the flow velocity of about 0.8 m/s is typical of the flow in ESPs).

The seed-particle size distribution (before and after the precipitation) was measured with the particle size-meter of laser light reflection type capable of measuring the particle size of 0.5–8 μm in 0.5 μm-wide ranges.

3. Results

We found that almost 90% of all particles of the cigarette smoke are particles smaller than 1 μm. This result is in good agreement with the results of other researchers [2].

3.1. Negative voltage polarity

The particle size distribution was measured before and after the precipitation process for negative voltage polarity and for primary flow velocities of 0.2 and 0.8 m/s. Each distribution is a result of averaging 2–4 measurements.

For a primary flow velocity of 0.2 m/s, the initial (i.e. before precipitation) number of particles I the range 0.5–8 μm varied from 15 000 to 21 000 with the majority of submicron particles (0.5–1 μm fraction). After precipitation, the number of submicron particles decreased to 70 at 25–32 kV while other fractions almost disappeared (1–5) even at 16 kV.

For a primary flow velocity of 0.8 m/s, the number of submicron particles (0.5–1 μm) decreased from 17 000–26 000 to 700 at 25 kV and to 135 at 32 kV. The number of particles of other fractions was negligible after precipitation.

The percentage of the precipitated particles for each fraction at a primary flow velocities of 0.2 and 0.8 m/s at negative voltage polarity is presented in Tables 1 and 2, respectively.

3.2. Positive voltage polarity

For a primary flow velocity of 0.2 m/s at positive voltage polarity, the initial particle number varied from 16 000 to 19 000. After the precipitation process, the number of submicron (0.5–1 μm) particles decreased to 600 at 32 kV. At a primary flow velocity of 0.8 m/s, the number of submicron particles decreased from 16 000–30 000 to 1500 for 25 kV and to 15 for 32 kV. The number of particles from other fractions counted by the size-meter at the duct outlet was negligible.

The percentage of the precipitated particles for each fraction at primary flow velocities of 0.2 and 0.8 m/s is presented in Tables 1 and 2, respectively.

3.3. Discussion

It is seen from Tables 1 and 2 that:

- in general, for both voltage polarities, the particle collection efficiency increases with increase in particle size and operating voltage, and it decreases with increase in flow velocity;

Table 1
Percentage of the precipitated particles at a primary flow velocity of 0.2 m/s, for negative and positive polarity

Fraction	Negative polarity/positive polarity							
	16 kV		20 kV		25 kV		32 kV	
0.5–1	52	3	94	90	99	100	100	97
1–1.5	77	1	99	100	100	100	100	100
1.5–2	86	1	99	100	100	100	100	100
2–2.5	88	1	99	100	100	100	100	100
2.5–3	90	6	99	100	100	100	100	100
3–3.5	97	17	100	100	100	100	100	100
3.5–4	97	22	100	100	100	100	100	100
4–4.5	100	41	100	100	100	100	100	100
4.5–5	100	62	100	100	100	100	100	100
5–5.8	100	100	100	100	100	100	100	100

Table 2
Percentage of the precipitated particles at a primary flow velocity of 0.8 m/s, for negative and positive polarity

Fraction	Negative polarity/positive polarity							
	16 kV		20 kV		25 kV		32 kV	
0.5–1	41	6	84	21	97	93	99	100
1–1.5	70	2	86	89	98	99	100	100
1.5–2	78	3	94	92	99	98	100	100
2–2.5	81	9	93	93	99	99	100	100
2.5–3	85	4	95	99	100	100	100	100
3–3.5	90	7	100	100	100	100	100	100
3.5–4	94	2	100	98	100	100	100	100
4–4.5	96	2	100	94	100	100	100	100
4.5–5	100	11	100	100	100	100	100	100
5–5.5	100	20	100	100	100	100	100	100
5.5–6	100	50	100	100	100	100	100	100
6–6.5	100	80	100	100	100	100	100	100
6.5–7	100	90	100	100	100	100	100	100
7–7.5	100	90	100	100	100	100	100	100
7.5–8	100	90	100	100	100	100	100	100

- no essential differences in the performance of the ESP model were revealed for negative and positive voltage polarities;
- for both voltage polarities, the efficient particle collection starts at a voltage higher than 20 kV; however, the particles larger than 5 μm are already efficiently collected at such a low voltage as 16 kV; the particle collection efficiency of the ESP at a low negative voltage (e.g. 16 kV) is higher than a similarly low positive voltage, although the collection efficiencies for both polarities are poor at such low voltages;
- for both voltage polarities the particle collection efficiency is about 99.5% for the submicron (0.5–1 μm) particles and 100% for the particles larger than 3 μm;
- for both voltage polarities the removal of particles larger than 3 μm is 100% at voltages higher than 20 kV; this means that there is no need for voltages higher than 20 kV to collect all the particles larger than 3 μm;
- high collection efficiency (higher than 99%) of the submicron (0.5–1 μm) and 1–3 μm particles requires higher voltages (25–32 kV);
- for both voltage polarities, the decrease in particle collection efficiency is larger for the low flow velocity (0.2 m/s).

The measurements revealed some features of the ESP performance regarding the collection of the submicron (0.5–1 μm) particles. The submicron particle collection efficiency is similarly high (99.5%) for both voltage polarities at a voltages higher than 25 kV, if the flow velocity is 0.2 m/s. However, the submicron particle collection efficiency at positive voltage polarity seems to be more dependent on velocity flow than that at negative voltage polarity (Fig. 1). As a result, at the flow velocity of

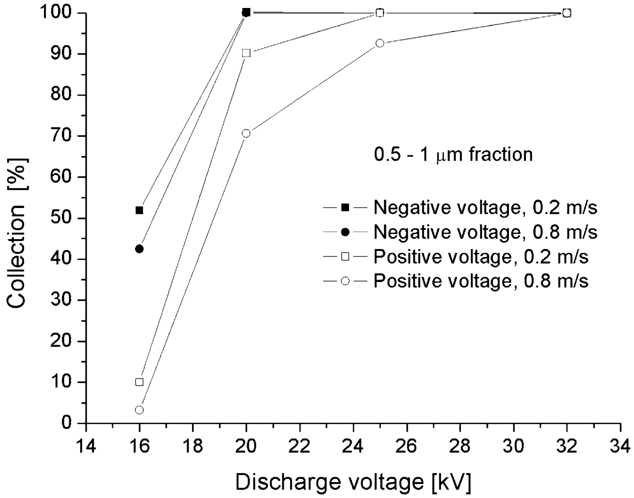

Fig. 1. Percentage of the precipitated submicron particles (0.5–1 μm fraction) as a function of discharge voltage for primary flow velocities of 0.2 and 0.8 m/s. Negative and positive polarity.

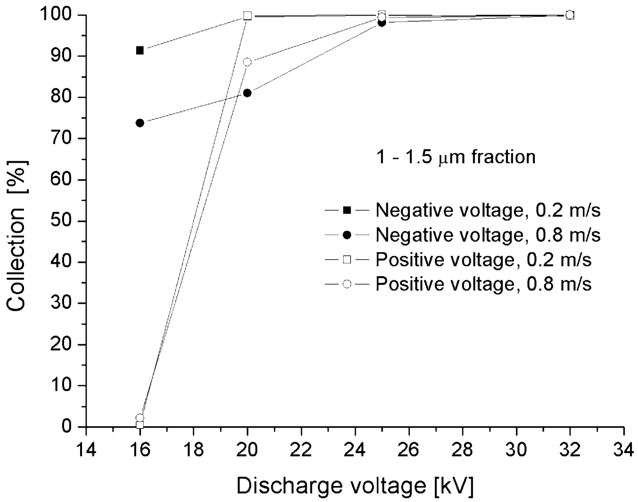

Fig. 2. Percentage of the precipitated 1–1.5 μm particles as a function of discharge voltage for primary flow velocities of 0.2 and 0.8 m/s. Negative and positive polarity.

0.8 m/s, the submicron particle collection efficiency at positive voltage polarity is lower than that at negative one unless the higher voltage is used (32 kV).

The most striking dissimilarity between the efficiencies of the collection of 1–1.5 μm particles for negative and positive voltage polarities occurs at the lowest voltage used (16 kV). The 1–1.5 μm particle collection efficiency is very low at the positive voltage of 16 kV, regardless of the flow velocity, while the same negative voltage results in the collection efficiency of about 90% and 80% at flow velocities of 0.2 and 0.8 m/s, respectively (Fig. 2).

4. Conclusions

The main results of this investigation are as follows:

- the submicron (0.5–1 μm) particles removal process starts to be effective at a voltage of 25 kV for both polarities;
- for both polarities voltage of 20 kV is high enough for precipitation of particles larger than 3 μm;
- the negative polarity voltage is more effective in precipitation of submicron particles, especially when low-voltage (16 kV) discharge is applied.

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References

[1] A. Mizuno, Electrostatic precipitation, IEEE Trans. Dielectr. Electr. Ins. 7 (5) (2000) 615–624.
[2] B.T. Chen, J. Namemyi, H.C. Yeh, J.L. Mauderly, R.G. Cuddihy, Physical characterization of cigarette smoke aerosol generated from a Walton smoke machine, Aerosol Sci. Technol. 12 (1990) 364–373.