THE SZEWALSKI INSTITUTE OF FLUID-FLOW MACHINERY
POLISH ACADEMY OF SCIENCES

TRANSACTIONS OF THE INSTITUTE OF FLUID-FLOW MACHINERY

119

GDAŃSK 2007

EDITORIAL AND PUBLISHING OFFICE

IFFM Publishers (Wydawnictwo IMP), The Szewalski Institute of Fluid Flow Machinery, Fiszera 14, 80-952 Gdańsk, Poland, Tel.: +48(58)6995141, Fax: +48(58)3416144, E-mail: esli@imp.gda.pl; now@imp.gda.pl http://www.imp.gda.pl/

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ISSN 0079-3205

TRANSACTIONS OF THE INSTITUTE OF FLUID-FLOW MACHINERY
Appears since 1960

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TRANSACTIONS OF THE INSTITUTE OF FLUID-FLOW MACHINERY

No. 119, 2007, 79-88

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Recent progress in electrostatic precipitation

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Abstract

Utilization of ionic wind and suppression of dust re-entrainment are important for performance of electrostatic precipitators (ESPs). Use of fibrous collection electrode is one of promising method. Ionic wind enhances dust migration towards collecting electrode, and fibers planted vertically on the collecting electrode decelerate ionic wind to prevent backward air flow that causes re-entrainment. In addition, gradient force at the fiber tip also works to prevent re-rentrainment. Other effective method, such as Ac energization and wet ESPs have also been used for cleaning suspended particles in tunnel, or for achieving very high efficiency together with simultaneous removal of gaseous pollutants. For indoor air, suppression of ozone production associated with corona discharge can be made using silver or titanium for positive discharge electrode. These recent developments will expand application field of ESPs.

Keywords: Electrostatic Precipitation; Ionic wind; Dust re-entrainment; Ozone

1 Introduction

Electrostatic precipitators have been widely used to remove fine particles because of high efficiency with low pressure drop. In these days, submicron particles in flue gas or exhaust from vehicles have been of concern. To improve collection efficiency for submicron particles, following points are important.

1. Suppression of backward gas flow caused by ionic wind, as well as utilisation of ionic wind to transport particles towards collecting electrode.
2. Minimization of abnormal reentrainment.

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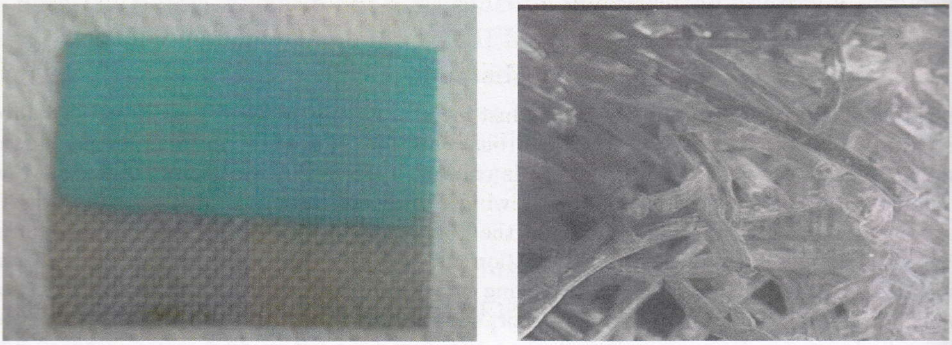
In addition, improvement of lifetime, especially that of discharge electrode has been required. ESPs have been used for factories and indoor air control, and suppression of ozone generation has also been important. ESPs can be used to remove gaseous pollutants such as NO_x, SO_x, volatile organic compounds, odors etc., by incorporating plasma chemical reactions.

2 ESP with fibrous/porous electrode

In order to slow down the ionic wind near the collection electrode and to minimise back flow, fibrous collection electrode has been proposed. Electrostatic flocking was used for fibrous collection electrode as shown in Fig. 1. Fine nylon fibers were attached on the electrode surface. Observed migration velocity becomes about 2 times higher compare with plate type electrode [1]. Particles are trapped at the tip of the fibers.

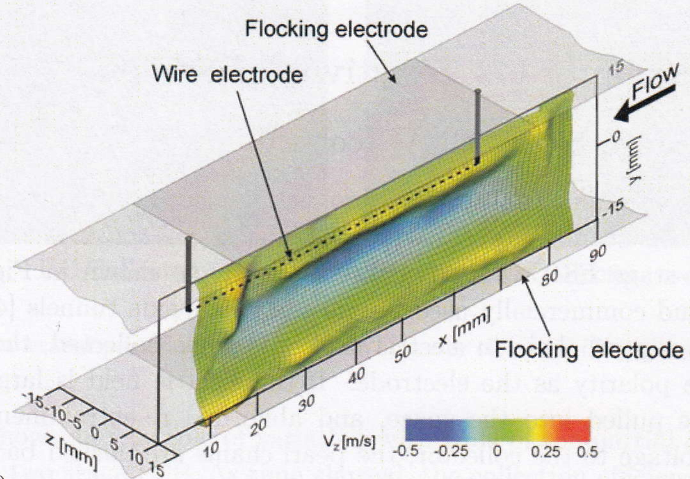


(a) (b)

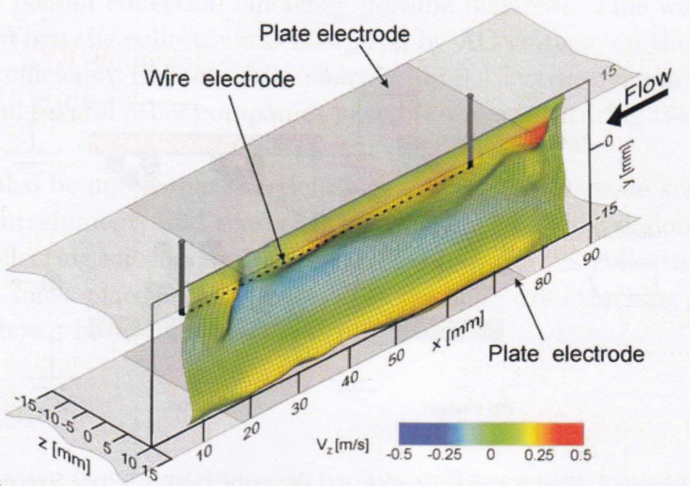
Figure 1. Electrostatic flocking electrode: (a) electrostatic flocking electrode (nylon fibers on metal mesh), (b) surface.

Figure 2 is the velocity of ionic wind measured by group of Prof. Mizeraczyk [2]. The wind velocity along the surface of the collecting electrode, directing vertical to the wire corona electrode, was clearly slower than that of conventional plate electrode (data not shown).

Smoke eliminators are very important for subway stations or buildings to keep visibility for evacuation. More than 90% collection efficiency is required for typical inlet dust concentration of 2 g/m^3, for at least 15 minutes. Mitsubishi Heavy Industries has developed a smoke eliminator, that is an ESP equipped with porous materials as the collecting electrode to reduce back flow of ionic wind and to achieve high efficiency with reduced size for installation on ceilings [3]. Metal mesh was attached on the surface of the porous material. Using this electrode configuration, size of the smoke eliminator was reduced to about a half to con-



(a)



(b)

Figure 2. Velocity of ionic wind along the electrode surface vertical to the wire discharge electrode (Z-direction) (measured by group of Prof. Mizeraczyk): (a) flocking electrode, (b) plate electrode.

ventional electrode system. In the experimental condition with the inlet dust concentration of about 3.8 g/m^3, 90% or higher collection efficiency was obtained with the gas flow velocity of 1 m/sec.

3 Collection of low resistivity particles

3.1 Two stage ESP with AC collector

Abnormal re-entrainment is a major problem in electrostatic precipitation of low resistivity dusts such as carbon soot from vehicle exhaust.

The two-stage ESP with AC collection part, as shown in Fig. 3, has been developed and commercially used for cleaning air inside tunnels [4]. Conductive particles form pearl chain in electric field, and when collected, they are charged to the same polarity as the electrode. If the electric field is large enough, the particles are pulled into the space, and abnormal re-entrainment takes place. With AC voltage to the collector, the pearl chains are pushed back to the plate electrode as the direction of the electric field changes.

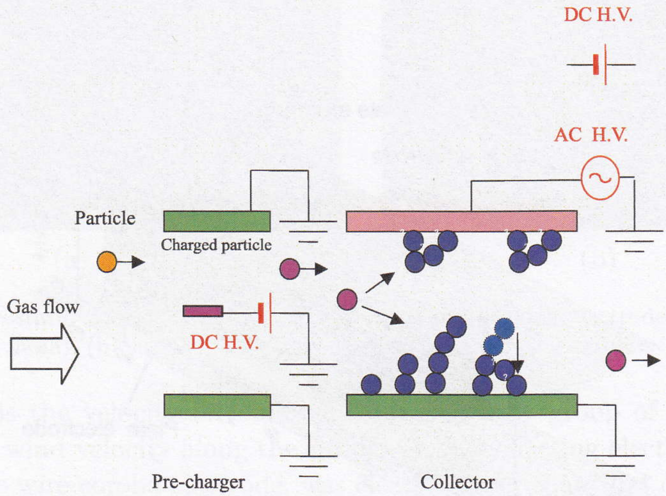


Figure 3. Two stage ESP with AC collector (Fuji Electric Systems).

Figure 4 shows the different configuration of collected particles on the electrode. In the DC energized collector, agglomerated particles formed pearl chains. This result indicates that the pearl chains are pulled into the space by the electrical force. In the AC collector, on the other hand, configuration of the agglomerated particles was spherical, indicating that these particles were not pulled back to the space.

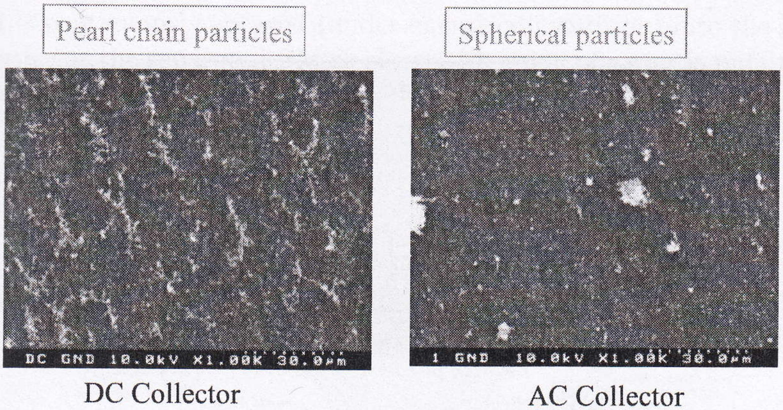


Figure 4. Agglomerated particles collected on the collector electrode (Fuji Electric Systems).

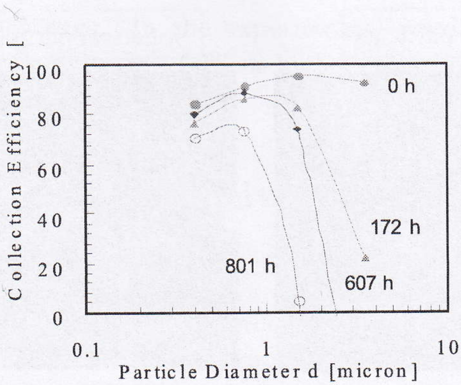
Figure 5 shows an example of variation with time of the partial collection efficiency of the two stage ESP. As time elapsed, the collection efficiency of the DC collector decreased due to beginning of abnormal re-entrainment of conductive particles collected on the electrode. Due to re-entrainment, agglomeration took place, and collection efficiency of larger particles drop sharply, and after 607 h operation, the partial collection efficiency became negative. This was due to agglomeration. When the collector was energized by AC voltage, on the other hand, the collection efficiency did not drop sharply. Fuji Electric System, Matsushita Eco-System and several other companies have been manufacturing two stage ESPs for tunnels.

It should also be noted that, particles are agglomerated inside an ESP due to abnormal re-entrainment, and diameter becomes large. This agglomeration can be used for collecting sub-micron particles [5]. On a fibrous collecting electrode, agglomeration takes place effectively because particles are attaching at the tip of the fibers as shown in Fig. 6 [5].

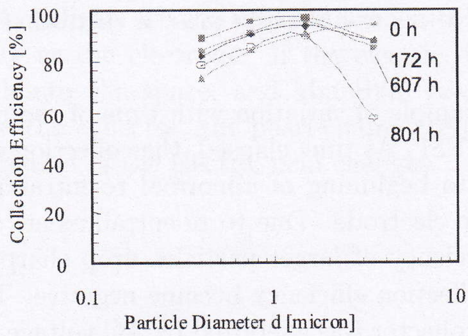
3.2 Wet ESP

Wet ESP can solve the re-entrainment problem. Dust resisitivity does not affect collection efficiency. Due to high efficiency, wet ESPs have been used in various factories such as steel plant and boiler plant, etc.

Figure 7 shows a wet ESP (WESP) manufactured by Mitsubishi Heavy Industries [6]. Flue gas is introduced horizontally. The discharge electrodes have long spikes for stable negative corona discharge. In the first section, most of the particulate matters (PM) are collected. The second section is independently energized from the first section. Remaining PM is further separated from the gas. Atom-

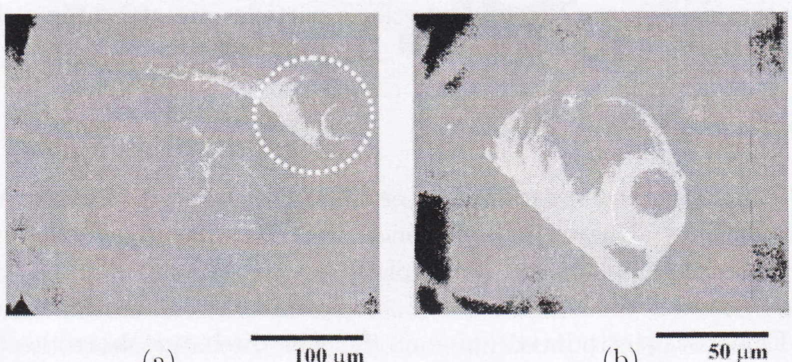


(a) DC collector



(b) AC collector

Figure 5. Time change of partial collection efficiency of the two stage ESP (Fuji Electric Systems).



(a) (b)

Figure 6. Collected cigarette particles on tip of fibers of flocking electrode.

ized water is continuously sprayed (under energized condition) into the collecting zone to wash out the separated PM as slurry. Ph-value of water is monitored and water treatment is made if necessary.

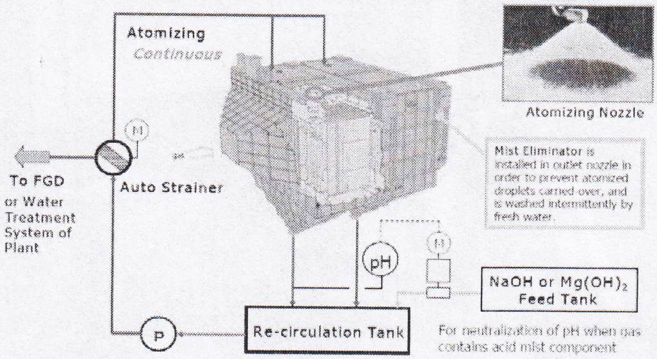


Figure 7. Wet ESP with holizontal gas flow and continuous spraying (Mitsubishi Heavy Industries).

If wet FDG (DeSOx system) is employed, the flue gas temperature is quenched to saturated water condition, and gaseous SO_3 is condensed as sulfuric acid mist (H_2SO_4), or SO_3 mist. Diameter of SO_3 mist was found to be very fine (around 30 nm), being too fine to be removed in FGD. Sub-micron particles are quite visible, and often result in a bluish plume from smoke stack. WESP is one of the best solutions for removing fine SO_3 mists.

3.3 ESP for removal of soot

Application of ESP to diesel exhaust cleaning is currently a challenging subject. Re-entrainment can be used for agglomeration of diesel soot. After agglomeration, coarse mechanical filters can be used for separation. Oxidation or removal of collected soot is necessary. Barrier discharges or sparking may be used for oxidation of soot.

Another attempt is to apply ESPs for road. Figure 8 shows the test site. Flat ESPs (total thickness: 300 mm) are used for separation of the road, vehicles and pedestrian. Wet or semi-wet ESP has been tested to remove PM and NO_x simultaneously. The collection electrode is wet-type, and at 1 m/s gas flow condition inside the ESP, 80% collection efficiency for sub-micron particles can be obtained. The corona discharge oxidize NO, and absorbed by catalyst set on both sides of the ESP. Paticles are introduced to the ESP by natural wind and air flow generated by vehicles.

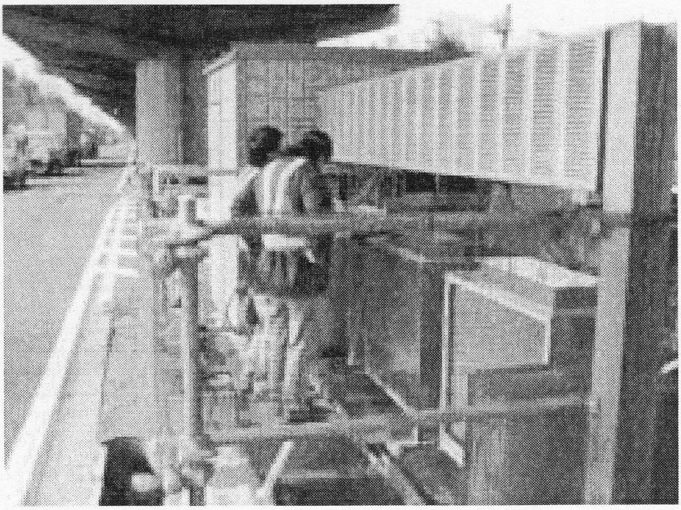


Figure 8. Field test of wet ESP for road separation (Environmental Remediation and Conservation Agency, Matsushita Eco-Systems).

4 Suppression of ozone generation

ESPs have been widely used for cleaning of factories, especially for machining. For indoor air cleaning, suppression of ozone due to corona discharge is very important. Material of discharge electrode affects the ozone generation [7].

Yehia et al., measured the ozone generation of corona discharge with different material of the discharge electrode. Ag is effective to reduce the ozone formation. Ag is, however, too fragile to be used for corona discharge electrode and therefore Ti has been proposed for the corona electrode. Figure 9 shows the comparison of ozone generation in wire-cylinder corona electrode. With positive corona, effect of Ag is apparent. However, with negative corona, effect of Ag is not apparent.

An AC voltage was superposed to DC voltage for a two stage ESP. As shown in the Tab. 1, the superposition of the AC voltage reduces the ozone generation while maintaining the collection efficiency almost constant. Use of silver electrode is effective for suppression of ozone generation. These results are very important to reduce the power consumption.

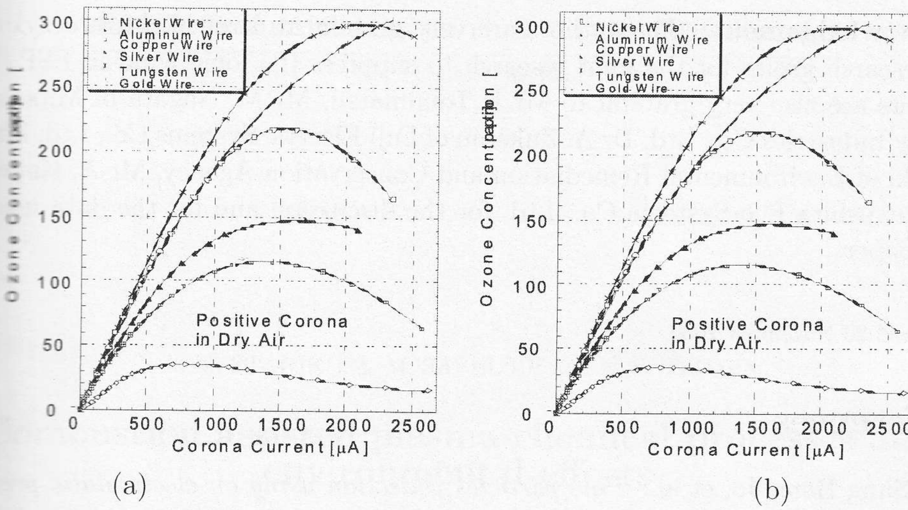


Figure 9. Effect of electrode material on ozone generation in positive and negative corona; (a) ozone generation in positive corona, (b) ozone generation in negative corona.

4.1 Conclusion

ESPs have been used for more than 100 years, however, new applications have been expanding. Novel development of ESPs will contribute to improve our living standard. One of important applications to be developed is to suppress airborne infection, and ESPs will also contribute to control bio-particles.

Table 1. Ozone generation and collection efficiency of an ESP for factory.

Electorode material	Voltage	V_{peak} (kV)	AC V_{pp} (kV)	V_{pp}/V_{peak} %	Ozone concentr. (ppm)	Collection efficiency %
Silver	+DC	12	0	0	0.013	99.42
	+DC+AC	12	2.4	20.0	0.010	99.53
	+DC+AC	12	6.2	51.7	0.009	99.35
Tungsten	+DC	12	0	0	0.035	99.41
	+DC+AC	12	2.4	20.0	0.033	99.48
	+DC+AC	12	6.3	52.5	0.030	99.25

Acknowledgement The authors are very grateful to Prof. J. Mizeraczyk an his research group for the joint research to suppress the ionic wind in ESP. Th authors are also very grateful to Mr K.Tomimatsu, Mr M. Nagata of Mitsubish Heavy Industries Co., Ltd, Dr A. Zukeran of Fuji Electric Systems Co., Ltd, Mr M Suzuki of Environmental Remediation and Conservation Agency, Mr A. Katatan of Matsushita Eco-Systems Co., Ltd, for the discussion and for the data used i this paper

Received 20 November 2006

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