For further development of ESPs

Akira Mizuno

Toyohashi University of Technology, Hibarigaoka 1-1, Tenpaku-cho, Toyohashi, 441-8580, Japan
Corresponding author: *mizuno@ens.tut.ac.jp*

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1. Introduction

It is well known that electrostatic precipitation has been contributed significantly to achieve clean environment [1, 2]. There are still requirements to this mature technology, such as to be more compact and efficient, long maintenance period, less usage of electric power, and bio-particle treatment.

Electrostatic precipitators have been using corona discharge to charge suspended particles. For indoor air cleaning, corona discharge is not preferable because of generation of harmful ozone and nitrogen oxides [3]. To avoid this problem, we have been studying a possible other means to charge the suspended particles in air to be treated. One possible method is to use induction charging [4]. When particles touch to one of the electrode on which electric field exists, a charge is induced on the particle. This is called induction charging, and is in proportion to the electric field. Therefore, we have tested several method to use induction charging for ESPs or for pre-charger of mechanical filter.

Non-thermal plasma technology has been derived from ESPs to promote chemical reactions at lower temperature by reactive radicals produced in NTP. This process could be used for control of gaseous pollutants and bio-particles [5].

In this paper, several novel developments of ESPs will be presented.

2. Synergetic use of ionic wind and suppression of dust reentrainment using piles on collection electrode

It has been reported that collection performance of ESPs can be improved significantly if ionic wind is properly used, and gradient force is utilized to suppress the re-entrainment, as depicted in Figure 1 [6, 7]. We have reported an ESP using an electrode made of electrostatic flocking, that can decelerate the ionic wind from the corona electrode and reduce the carryover of particles near the collecting electrode. The protruded tip of each fibers converge the electric field and attract particles due to gradient force. This force reduces the re-entrainment of particles.

Figure 2 shows the ESP used for the test. Nylon piles with volume resistivity of less than10^8 Ωm, 2 μm in diameter and 1 mm in length were planted on the surface of the collection electrode using electrostatic flocking.

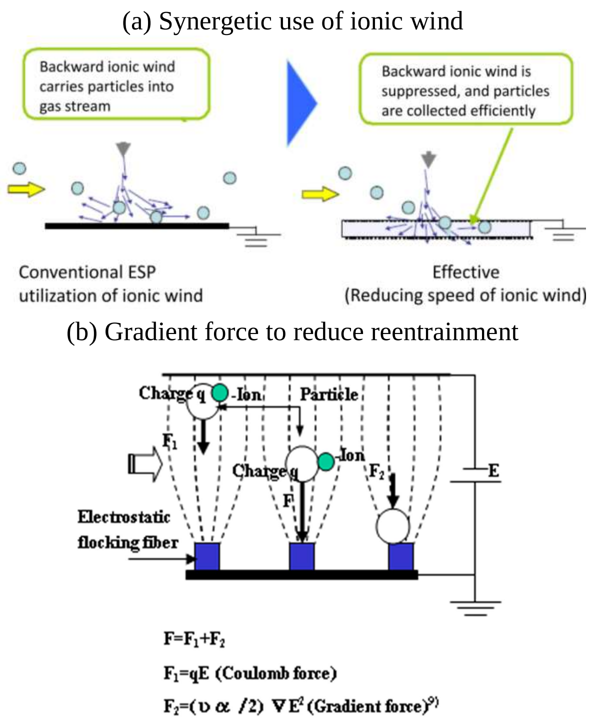


Figure 1. Model of precipitation using ionic wind, and suppression of reentrainment

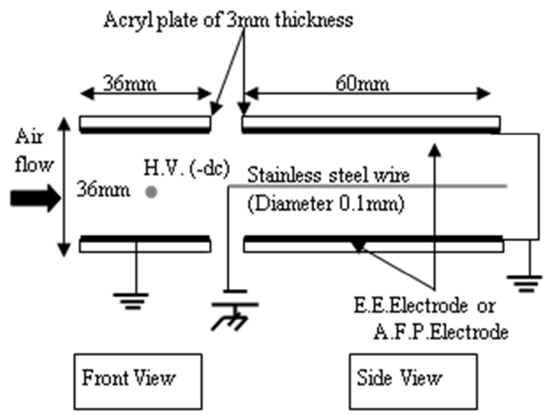


Figure 2. The ESP used for the test

Using suspended particles of cigarette smoke in room air, the test was made with the detention time of 0.06 sec. The V-I characteristics with and without the flocking was almost the same at room temperature and 70% relative humidity. Penetration of 0.3–0.5 μm particle was 5% (with the piles) vs. 11% (flat electrode). The microscopic observation indicated that most of the smoke particles were attached at the tip of the piles. This result indicates that the use of piles on the electrode surface can reduce the size, or increase the collection efficiency. The PIV measurement also indicated that the ionic wind along the electrode surface was slower with the pile [8].

3. Suppression of dust deposit at the tip of corona tip

Dust build-up on discharge electrode is an important problem of ESPs to be solved. In two stage ESPs for small scale applications, an effective corona discharge electrode for anti-dust build-up has been developed. The ground electrode has many holes in which gas pass through, and the corona discharge electrode is located at the center of each hole. The corona point is at the very end of the discharge electrode. With this configuration, ionic wind is generated towards the same direction of the main gas stream, and at the corona point, the speed of ionic wind is in the order of 10 m/s, and this high speed gas stream reduces the dust build-up at the tip of the corona electrode.

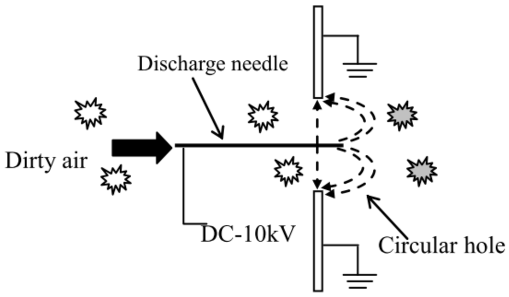


Figure 3. Corona electrode to reduce dust build-up

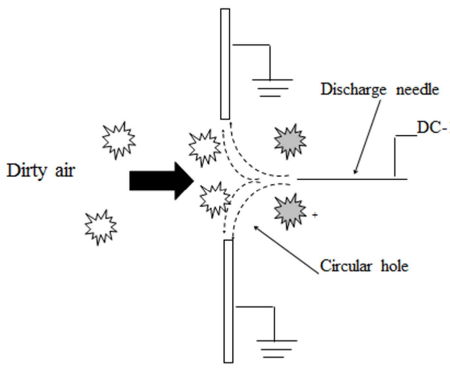


Figure 4. The other electrode for comparison

The continuous field tests to comapre the V-I characteristics indicated that the apparatus in Fig. 3 could be used for more than 1,500 h, whereas in the same dust condition, the corona current in the electrode shown in Fig. 4 reduced significantly after 300 h operation. The electrode system in Fig. 3 has been used as a pre-charger of the two-stage ESP [9].

4. Use of induction charging

Electrostatic flocking was made using carbon fibers to coat the surface. Diameter of the carbon fibers used was around 7 micrometer. The fibers were cut with length of 0.8–2.0 mm. An aluminum plate of 50 mm square and 1.0 mm thick was used as the base. Using conductive paste, the fibers were fixed using electrostatic flocking. After fixing, the length of the fibers were trimmed to be 0.8 mm or 0.4 mm. Figure 5 shows the experimental apparatus. 3 different electrodes, without fiber, with 0.4 mm fiber, and with 0.8 mm fiber coating were compared. The electrode separation, the gas flow rate and the applied voltage were varied for the test. Collection efficiency for suspended particles of 0.3 μm diameter in air was measured using an optical particle counter (KANOMAX Model-3905). Table 1 tabulates the measuring condition.

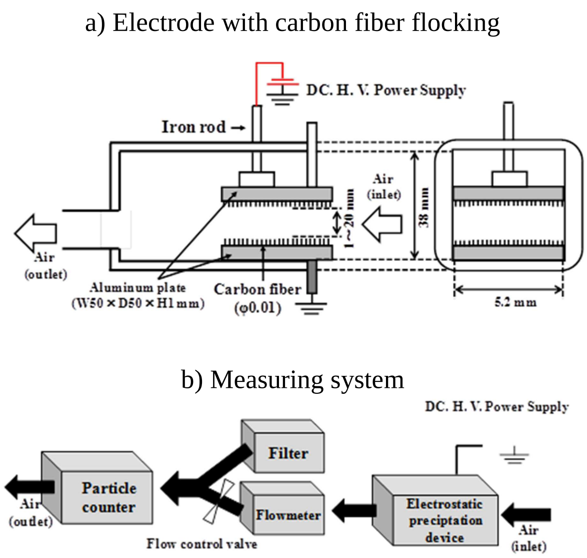


Figure 5. Experimental apparatus using the parallel electrode system with carbon fiber flocking

Table 1. Measurement condition

Condition	Al plate	Electrostatic flocking (0.4mm)	Electrostatic flocking (0.8mm)
Interelectrode distance [mm]	1-20	3-4	2-20
Flow rate [mL/min]		200-3000	
Applied voltage [kV]	0-20	0-3	0-10

Figure 6 shows the collection efficiency vs. gas flow rate when the electrode separation (base to base) was 3.0 mm, and the average electric field strength (voltage devided by base separation between two plate electrode) of 500 V/mm. No corona current was observed in this condition. With increasing gas flow rate, the collection efficiency decreased. Without the fibers, the collection efficiency was around 30%. With the fibers, the efficiency increased.

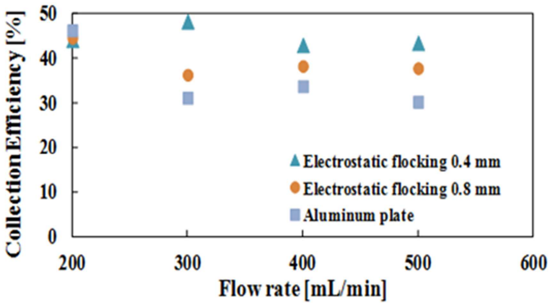


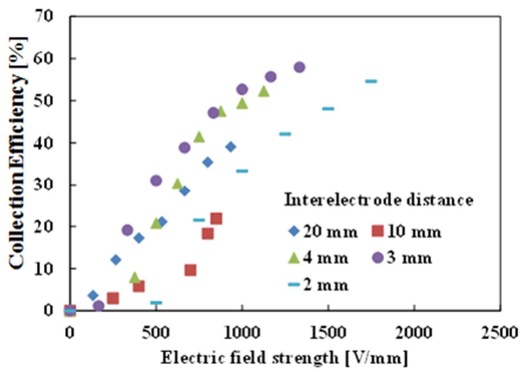
Figure 6. Removal efficiency vs. gas flow rate (Electrode base separation: 3 mm, Applied voltage: 1.5 kV)

Figure 7 compares the collection efficiency vs. electric field strength, with the air flow speed kept constant at 0.03 m/s. The current was monitored to be zero, and the voltage was adjusted within the range of no current. The separation of the electrode base tested was between 3.0 and 20.0 mm.

Regardless of the electric field of the electrode distance within the current was zero, the maximum collection efficiency was around 55–60%. This value indicates that most of the suspended particles having natural charge were collected.

It should be noted that a weak corona discharge is generated, the collection efficiency is increased significantly[10].

a) The electrode with the fiber of 0.8 mm length



b) The electrode with the fiber of 0.4 mm length

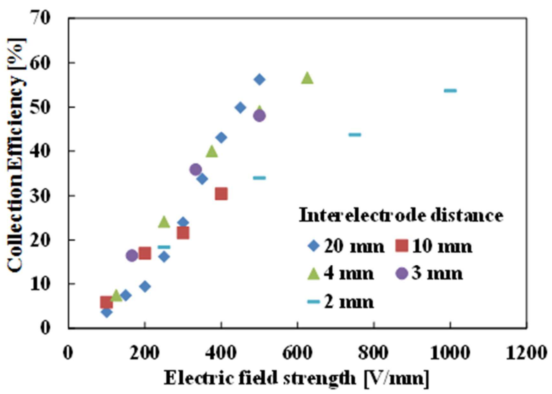


Figure 7. Collection efficiency vs electric field strength with the gas speed of 0.03 m/sec

5. Induction charging for dust collection

The slit-type electrode assembly was tested as shown in Figure 8 to evaluate the induction charging to be used for suspended particles in room air. The electrode is made of L shaped electrode set parallel with 4 mm separation. For comparison, the parallel plate electrodes with the fibers of 0.4 mm length were used with the separation of 4 mm between the electrode base. Table 2 is the measuring condition.

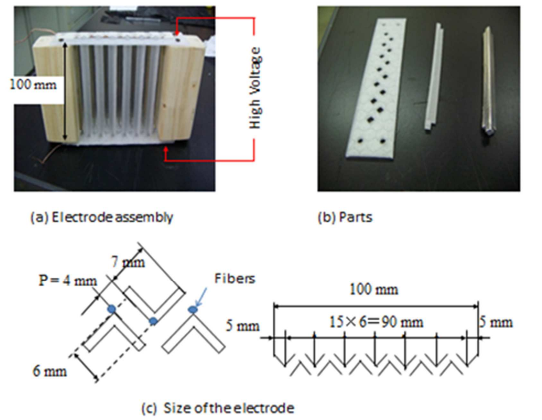


Figure 8. The slit-type electrode assembly

Table 2. Measuring condition for the slit-type electrode assembly

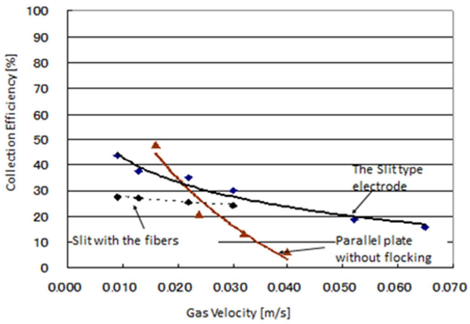
	Gas flow rate [ℓ/min]	Cross sectional area of the gas inlet [mm^2]	Gas velo-city inside the ESP [m/s]	Deten-tion Time [sec]	Surface area of the electrode [mm^2]
Slit type	6.91	3840	0.03	0.2	11520
	Cross section: 12 Electrode for the slit type assembly of 4×80mm are lined. Effective width of the parallel electrode is 6mm				
Para-llel plate	0.36	200	0.03	1.67	5000
	Square plate 50 x 50 mm, 4 mm separation				

As shown in Figure 9 (a), with the E-field strength of 500 V/mm, the slit-type electrode system had the collection efficiency of about 45% at 0.01 to 0.02 m/s gas velocity. This value was almost the same as that of the parallel plate electrode system. However, the collection efficiency of the parallel plate electrode dropped quickly with the increasing gas velocity. The slit-type has the electrode with L-shaped cross-section, which is more suitable for the suspended particles to collide for induction charging compare with the parallel plate electrode in which the air flow is more uniform, resulting in less collision of the suspended particles to the electrode.

Figure 9 (b) shows the collection efficiency with the E-field of 1000 V/mm. With the increasing in the E-field, the maximum collection efficiency was around 50%, and collection efficiency of the slit type electrode assembly was lower than the parallel plate. Flocking of the fibers increased the collection efficiency of the slit type electrode assembly.

In any case, the efficiency was around 50%. This result indicates that, for collection of suspended particles with no charge, these electrode assembly without corona discharge do not work.

a) E-field of 500 [V/mm]



b) E-field of 1000 [V/mm]

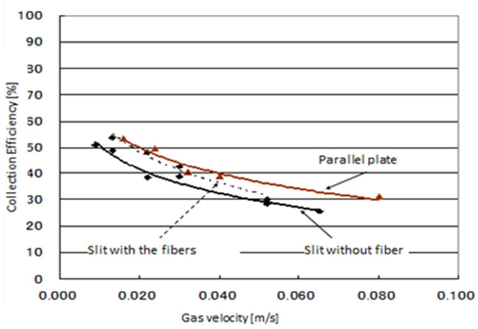


Figure 9. Collection efficiency vs. Gas velocity

6. Lethal effect of corona discharge on microbes

Corona discharge, or non-thermal plasma generates oxidative radicals that have lethal effect to microbes. ESPs, therefore, are suitable tool to control microbes and viruses, by not only collecting them, but also destroy them.

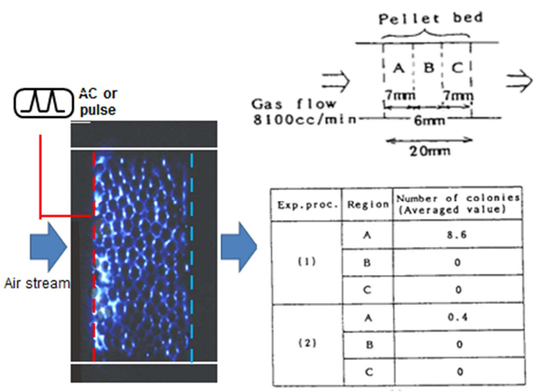


Figure 10. Lethal effect of Non-thermal plasma on microbes

Figure 10 shows one of the first report to use NTP to destroy microbes which are electrostatically collected [11].

We have reported various methods to control bacteria and viruses, and the mechanism of destruction [12, 13]. The use of ESPs as one of non-thermal plasma which generates reactive radicals, will be important to protect diseases.

7. Conclusion

ESPs are regarded as a mature technology, there are still various possible improvements. Ionic wind and gradient force are important to be considered in future design. Use of induction charging is also important for reducing power consumption.

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