Electrostatic Precipitator Using Induction Charging

A. Katatani¹, H. Hosono², H. Murata², H. Yahata², and A. Mizuno³
¹Panasonic Environmental Systems & Engineering Co., Ltd., Japan
²Panasonic Ecology Systems Co., Ltd., Japan
³Department of Environmental and Life Sciences, Toyohashi University of Technology, Japan

Abstract—The authors have had an idea that the power consumption in electrostatic precipitators, ESPs, might be decreased drastically if particles are touching to a conductive electrode in electric field, and are charged by induction charging. One reason is the fact that, in a corona discharge, most of the energy of accelerated electrons near the discharge electrode is wasted by bombardment to neutral molecules without ionization. To verify this idea, the authors have carried out an experiment using two-stage-electrodes sets. The first set of electrodes is made of the flocking electrode covered with ACF (Activated carbon fiber). DC high voltage was applied to the electrodes set. The voltage value was adjusted to be below the corona starting voltage. The second set of electrodes made of flat plates works as a collector of charged particles. This is designated as “a two-stage ESP with induction charging”. Varying the gas velocity inside the ESP, the collection efficiency of room-particles was measured. The result showed that the ESP was able to collect particles without corona discharge. This study implies the possibility of ESPs which can minimize the electrical power consumption.

Keywords—Electrostatic precipitator, electrostatic flocking, re-entrainment, induction charging

I. INTRODUCTION

Electrostatic precipitators (ESPs) have been widely adopted for purifying exhaust from motor-vehicle-tunnels or others [1]–[7]. Trend of the development of these ESPs has been to reduce the size by increasing the wind velocity. As a result, power consumption has been increasing recently, as shown in [8], [9].

There are studies on charge and sedimentation of fine particles. Some reports have shown that particles in diesel-exhaust are charged either positively or negatively [10]–[14]. Several studies have indicated that, in many cases, suspended particles in air have charge [15]–[20]. For sedimentation of fine particles inside ESPs, gradient force in non-uniform electric-field plays an important role [21]–[23].

To improve collection efficiency of ESPs, there is a study to use the electrodes with nylon-piles (prepared by electrostatic flocking) that generate strong gradient-force at the tip of piles [24]. Furthermore, there are studies reporting on the phenomenon of re-entrainment which is inevitable to ESPs [25], [26]. The re-entrained particles are electrically charged by induction charging [15], [27]–[30].

Taking these reports into account, the authors have the idea that the power consumption of ESPs can be decreased drastically if induction charging is used. The purpose of this study is to clarify the process in which temporarily attached particles onto the electrostatic-flocking electrodes are re-entrained with induction charge, and are collected by the electric field.

Through the experimental observation, the new-concept of ESP using induction charging is discussed.

II. METHODOLOGY

The experimental ESP is composed of the charger in the first stage and the collector in the second stage. To prepare the electrode with fibers, electrostatic-flocking is used. The electrode-plates (flocked-plates, hereafter) are used as the charger. How to make this flocked-plate is described as follows.

The electro-conductive glue (Three-Bond 3303G), which is mainly made from silver-paste and silicon-resin, is applied on each one side of stainless-steel-plate (SUS304, 36×40 mm, 0.4t) as base-plates for electrostatic flocking. Activated carbon fiber (ACF, production code CO6343 made by TORAY) is cut into the length from approx. 0.1 to 3 mm by using scissors to make ACF piles. The ACF piles are thrown in a device for electrostatic flocking, to which dc voltage is applied. Then, some ACF piles contact to the adhesive glue on the surface by the effect of circulation-wind in the device, and are finally fixed to form the flocked-plates.

A part of the craft-process of the flocked-plates is shown in Fig. 1.

The layout/electric-circuit of the flocked-plates in the charger is shown in Fig. 2, where twenty-four flocked-plates are arranged parallel with the gap of 10 mm. Two plates at the end points are not flocked at all. In addition, the surfaces of twelve flocked-plates at leeward are facing to the opposite direction of the flocked surfaces at windward.

The applied voltage to the charger was determined according to the concept to use induction charging that does not want corona-discharge from flocked-plates but does need the electric field strength as strong as possible. Thus, taking into account the V-I characteristics in Fig. 3, the voltage of -2.4 kV which realizes the maximum electric field strength without forming corona-discharge, was determined.

The collector consisted of parallel electrodes, and was placed downstream of the charger. The shape of all the electrode-plates in the collector is 94×280 mm (0.4t). Seven
grounded-plates and six energized plates are alternately arranged with 10 mm gap. The applied voltage to the energized-plates is -9 kV, which does not generate corona-discharge.

The schematic diagram of test equipment and the specification of test equipment are shown in Fig. 4 and Table I, respectively. The particles to be collected in this study were those suspended in the air of the laboratory room. By measuring the wind velocity with the wind velocity meter #12 at the inlet of the inlet duct, the wind velocity in the charger duct #3 was adjusted with a fan-speed-controller in order to obtain four levels of wind velocity of 2, 5, 8 and 11 m/s. The concentration (count-concentration of particle diameter 0.3 µm over) of particles in the room-air was measured by the particle counter of #11, whose two sampling tubes at the inlet-duct and the outlet-duct were alternately switched, to calculate the collection efficiency.

The collection efficiency was measured for the three cases of different applied voltages. Each case includes the efficiency with four levels of the wind velocity.

### III. DISCUSSION

#### A. Case 1: charger -2.4 kV, collector 0 kV

The purpose of Case 1 is to evaluate the collection efficiency of the charger only. The measured result is shown in Fig. 5...
which indicates the collection efficiency of all the particle-diameters of 0.3 μm over. As the dispersion of three-times-measurement is within ±1% to the average indicated in solid line, there is repeatability. The collection efficiency was less than several percent.

**B. Case 2: charger 0 kV, collector -9 kV**

The purpose of **Case 2** is to evaluate the collection efficiency of the collector only. The measured result is shown in Fig. 6. As the dispersion of three-times-measurement is also within ±1% to the average in solid line, there is repeatability. The collection efficiency was less than several percent. At the point of wind velocity 2 m/s, the collection efficiency is almost 25%, which means the extremely-greater value compared to other velocity levels. This tendency is similar to **Case 2** of using the collector only. Therefore, this is the characteristic strongly affected by the collector.

At this moment, the combined collection efficiency of operating both charger and collector simultaneously can be calculated using (1), although it should be under the condition that both parts do not interfere in each other.

\[
Z = \left(1 - \left(1 - \frac{X}{100}\right)\right) \times 100\%
\]  

Where, \(X\) is the collection efficiency of “charger only” under certain wind-velocity condition and under certain particle-diameter. Let \(Y\) as the collection of “collector only” under the same conditions of velocity and diameter.

According to the above mentioned idea, the synthesized collection efficiency obtained from calculating the two cases of collection efficiency in operating “charger only” and “collector only” is shown as the broken line in Fig. 8. The solid line in the figure indicates the result from the actual measurement, which has already shown, for the comparison.

Here, the following fact can be noticed. That is; although the calculation (the broken line) resembles the measurement (the solid line) in the velocity characteristics of collection efficiency, the measured characteristic is higher than the calculated one in all points. This means that the charger and the collector are not independent of each other in case of applying voltage to both parts. That is; the particles which have contacted the charger or been collected at the charger temporarily do re-entrain with being electrically charged by induction charging, then, the charged particles are collected in the second stage collector with strong electric field. This might be the reason of the higher characteristic of measurement. The reference [31] reports the aspects of particle-sediment/collection measurement with electric fields existing in both parts. That is; this is the evaluation for the two-stage-ESP.

The measured result is shown in Fig. 7. As the dispersion of three-times-measurement is also within ±1% to the average in solid line, there is repeatability, too. At the point of wind velocity 2 m/s, the collection efficiency is about 40%, which means the much-greater value compared to other velocity levels. This tendency is similar to **Case 2** of using the collector only. Therefore, this is the characteristic strongly affected by the collector.

The three cases (**Case 1** of “voltage to the charger only”, **Case 2** of “voltage to the collector only” and **Case 3** of “voltage to both”) should be synthetically discussed as follows.

\[
Z = \left(1 - \left(1 - \frac{X}{100}\right)\right) \times 100\%
\]
by using one-stage-ESP without corona discharge-parts. The report includes that the re-entrained particles with induction charging can be re-collected in strong electric field even if corona discharge does not exist, which is similar to the result of this study.

In order to confirm how much or less there is “particle-attaching” to the surfaces of ACF on flocked-plates in case of using flocked-plates in ESPs, the observation with a SEM (scanning electron microscope, Hitachi S-3600N, gold evaporation, acceleration voltage 10 kV, magnification 3000) was done. The observation results are shown in Fig. 9. The aspect of an ACF surface on an unused flocked-plate is shown in Fig. 9(a). On the other hand, Fig. 9(b) displays the aspect of an ACF surface under the condition for the ESP to be operated for approx. 10 h in the room atmosphere with applying -2.4 kV to the charger.

Comparing (a) with (b), no particle-attaching of room dust can be seen on (a). On the other hand, small dust of “1 µm under” on the ACF surface is found on (b). Although it seems that the ACF diameters of (a) and (b) slightly differ from each other, both diameters are within the ACF product-specification of diameter from 5 to 10 µm.

Any other differences on both figures cannot be found.

IV. CONCLUSION

Using the charger composed of metal plates to be electrostatic-flocked with activated carbon fiber, a dc voltage which does not make them generate corona-discharge was applied to the charger. In addition, the collector to be composed of parallel flat-plates was installed at the position after the charger to form a two-stage-ESP. Making room-particles in the atmosphere pass through the ESP, the collection efficiency was measured by using a particle-counter. As a result, the following points were found.

1) Under the condition of wind velocity 2 m/s, the collection efficiency on all particle-sizes of “diameter 0.3 µm over” was measured as approx. 40% (No generation of corona discharge).
2) The above-mentioned collection efficiency was greater than the synthesized efficiency calculated by using the measured efficiency of both “charger only” and “collector only”.
3) The reason is as follows. That is; re-entrained particles from flocked-plates in the charger might be electrically charged by induction charging, even in case of using chargers without generating corona-discharge. And the particles, which obtain electric charge by induction charging, can be collected at the leeward collector with strong electric field. These effects might have an influence on the higher measured efficiency compared to calculated efficiency.
4) Small room-dust of “1 µm under” on the surface of the activated carbon fiber in flocked-plates was found.

REFERENCES
