Relationship between Discharge Electrode Geometry and Ozone Concentration in Electrostatic Precipitator

Yoshiyasu Ehara[1], Daiki Yagishita[1], Toshiaki Yamamoto[1], Akinori Zukeran[2], Koji Yasumoto[2]
(1 Musashi Institute of Technology 1-28-1 Tamazutsumi, Seyagaya-ku, Tokyo 158-8557 Japan.
E-mail: ehara@ee.musashi-tech.ac.jp
2 Fuji Electric Systems Co., Ltd. 1, Fuji-machi, Hino-city, Tokyo 191-8502, Japan. E-mail: zukeran-akinori@fesys.co.jp)

Abstract: In this research, the relationship between discharge electrode geometry and ozone generation in Electrostatic precipitator (ESP) has been experimentally investigated. The experimental ESP was two-stage-type which composed of a precharger, followed by the collecting section. The precharger consists of high voltage electrodes and grounded electrodes. The high voltage electrode was saw-tooth type and the grounded electrodes was plate type. The collecting electrode section had a parallel-plates configuration. The electric field distribution of saw-tooth electrode neighborhood was calculated. The relationship between the ozone generation and electric field distribution of the saw-tooth neighborhood was investigated. The geometry of the saw-tooth electrode changed a tip angle and the number of saw-tooth. The relationship between the saw-tooth electrode geometry and ozone generation was also investigated.

Keywords: Electrostatic Precipitator, Ozone, Saw-tooth type Electrode, Corona Discharge

1 INTRODUCTION

Diesel Exhaust Particles (DEP) is the problem of air pollution in high concentration the unsociable space such as long-distance tunnels. ESP is installed in a tunnel to collect particulates that principally involve DEP. The tunnel of metropolitan area under the ground needs an additional system due to densely-populated area. ESP collects the particle by the corona discharge. Therefore, ESP generates harmful ozone in the human body and the environment without fail [1, 2]. Ozone oxidizes NO contained in the diesel exhaust gas, and increases the NO_2 concentration included in the atmosphere. Moreover, the ozone causes the photo-chemical smog. In addition, the decrease of photochemical oxidant is desired in urban region. Therefore, the decrease of the ozone generated from ESP is requested.

When a positive voltage is applied to the wire of the discharge electrode, ozone generation is very low [3]. However, the main problem of this system is breaking of wire. Authors considered the ozone concentration in three types of discharge electrodes, wire, thin plate, and saw-tooth in both positive and negative voltage. Consequently, the plate type is the best in a positive polarity and the saw-tooth type is best in the negative voltage [4].

In this research, the relationship between discharge electrode geometry and ozone generation in ESP has been experimentally investigated. The experimental ESP was two-stage-type which composed of a prechager, followed by the collecting section. The high voltage electrode in the precharger was saw-tooth type. The relationship between the saw-tooth electrode geometry and ozone generation was investigated. The geometry of the saw-tooth electrode changed a tip angle and the number of saw-tooth.

2 EXPERIMENTAL METHODS

A schematic of experimental apparatus is shown in Fig. 1. The gases exhausted from the diesel engine were diluted with air and introduced into ESP. Gas flow velocity was 7 m/s. Ozone concentration behind ESP was measured by ozone monitor (Ebara Jitsugyo, EG-2001). A particle counter (Rion, KC-01B) was used to measure the number of particles for particle sizes larger than 0.3 μm. The numbers of particles were measured at upstream and downstream of ESP.

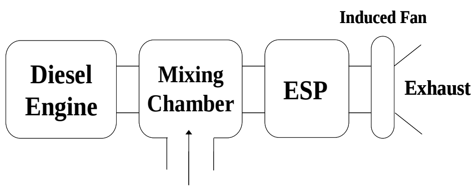


Fig. 1 Schematic of experimental apparatus

The experiment is conducted by two-stage-type ESP composed a precharger and collecting section. ESP was constructed and their dimension is shown in Fig. 2. In the precharger section, high voltage electrode of a saw-tooth was used to experiment. The discharge gap was 9 mm. Each ground electrode used a plate. Negative DC voltage was applied to high voltage electrode in the precharger section. The collecting section had a parallel-plates configuration. The length between electrodes is 9 mm. DC 7.5 kV was applied to high voltage electrode in the collecting section. The corona discharge luminescence was observed from the front of the precharger by a digital camera

Electrode structures of the precharger in ESP are shown in Table 1. In this experiment, a saw-tooth electrode of 0.1 mm thickness was used. The geometry of the saw-tooth electrode was changed a tip angle with 15°, 29°and 52°, respectively. The pitch length of three electrodes was all 2.5 mm, and numbers of saw-tooth were 27.

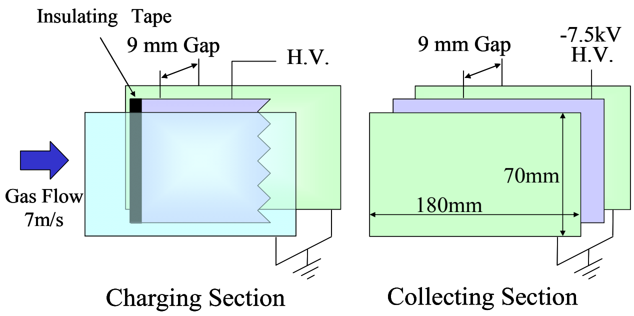
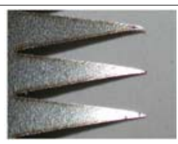


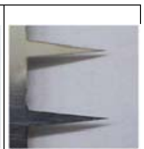
Fig. 2 ESP configuration

Table 1 Saw electrode that changes tip angle

Saw Electrode			
Tip Angle	15°	29 °	52 °
Pitch [mm]	2.5	2.5	2.5
numbers of saw	27	27	27
Depth [mm]	10	5	2.5

In the examination of the optimum electrode geometry in low ozone ESP, the numbers of saw-tooth were changed as shown in Table 2. These were 27, 13, 8 and 6, the electrodes pitch were 2.5, 5, 7.5 and 10, respectively. The tip angle of four electrodes was all 15°.

Table 2 Saw electrode that changes numbers of saw

Saw Electrode				
Tip Angle	15 °	15 °	15 °	15 °
Pitch [mm]	2.5	5	7.5	10
number of saw	27	13	8	6
Depth [mm]	10	10	10	10

3 RESULTS AND DISCUSSION

3.1 Characteristic of Saw Tip Angle

The collection efficiencies for several saw tip angle are shown in Fig. 3. The electrodes were used the geometry of the saw-tooth electrode shown in Table 1. The collection efficiencies increase with increasing discharge current in any electrode. It is shown that the saw tip angle doesn't influence the collection efficiency. An electrification of the particle depends on an amount of the ion generation. Therefore, it is thought that there are not so many differences in the amount of the ion generation even if the saw tip angle changes when the electrical discharge current value is equal.

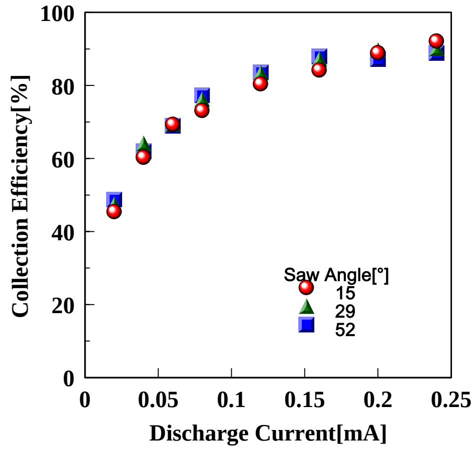


Fig. 3 Collection efficiency for several saw tip angle

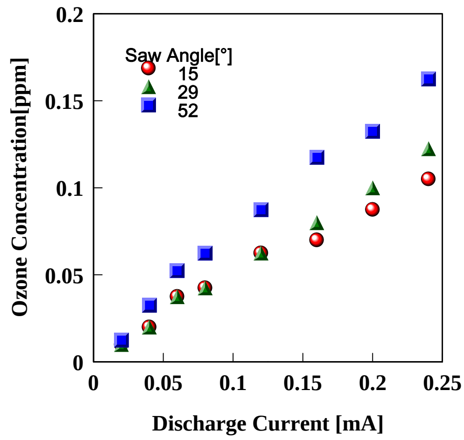


Fig. 4 Ozone concentration for several saw tip angle

The ozone generation characteristics for several saw tip angle are shown in Fig. 4. The ozone concentration is low in order of the angle of 15°, 29 °and 52°. The ozone concentration is low like a pointed electrode. The electric field distribution of saw-tooth electrode neighborhood was changed by the saw tip angle. This is thought to be changeable the discharge area where ozone is generated.

Then, the observation result of the discharge luminescence in the saw-tooth electrode is described. In this study, it was thought that the discharge luminescence areas of visible wavelengths are proportional to ozone generation area. The discharge luminescence image was taken with the digital camera, and the luminescence area of the visible wavelengths was measured. The ozone concentrations as a function of discharge luminescence area are shown in Fig. 5. The ozone concentrations increase with increasing discharge luminescence area. The ozone concentration shows the characteristic of almost the same inclination to the discharge luminescence area in any saw-tooth angle. It is considered that the ozone generation depends on the discharge luminescence area. Consequently, it was confirmed that the geometry of the saw-tooth electrode where the discharge luminescence area became small was suitable in low ozone ESP.

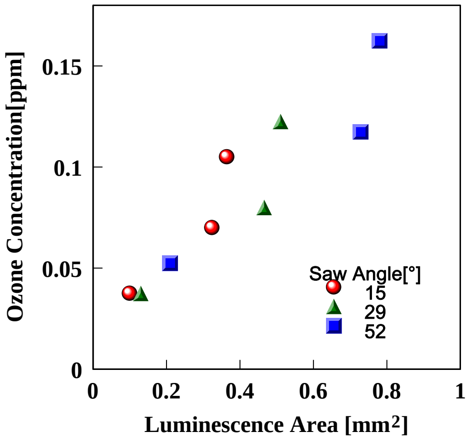


Fig. 5 Ozone concentration as a function of luminescence area

3.2 Characteristic of Numbers of Saw-tooth

In this section, the relationship between the numbers of saw-tooth electrode and ozone generation was investigated. The electrodes were used the geometry of the saw-tooth electrode shown in Table 2. The numbers of saw-tooth electrode were 27, 13, 8 and 6 respectively. Tip angle of four electrodes was 15°.

The collection efficiencies for several numbers of saw-tooth electrodes are shown in Fig. 6. The collection efficiencies increase with increasing discharge current in any electrode. This figure shows that the collection efficiencies decrease with decreasing the numbers of saw-tooth electrode. The particles are electrified by ion generated with discharge. In the saw-tooth electrode of few numbers, it is considered that the collection efficiency decreases due to decreasing of the area in ion generation.

The ozone concentration characteristics for several number of saw-tooth electrodes are shown in Fig. 7. In Fig. 7, any discharge current is 0.24 A. The ozone concentration decreases with decreasing the numbers of saw-tooth electrode. It is considered that this reason is a decrease of the generation point of the discharge according to the area of the production of ozone. The collection efficiency characteristics at 0.24 A

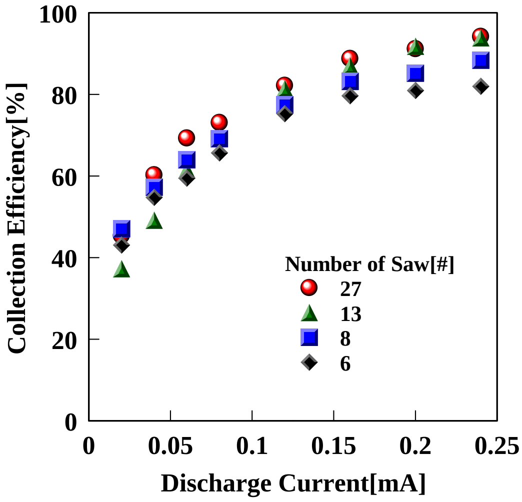


Fig. 6 Collection efficiency for several number of saw-tooth electrodes

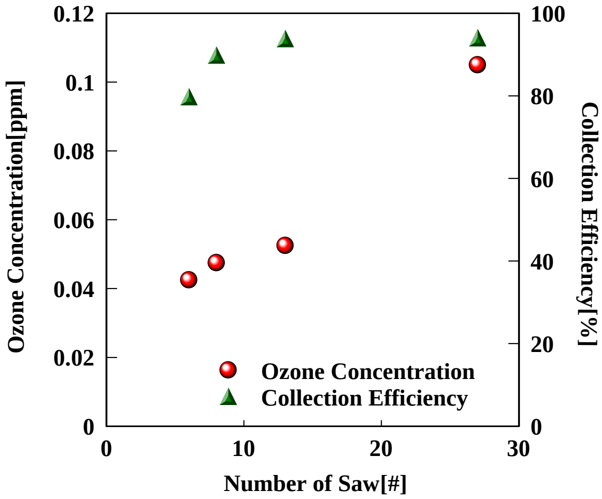


Fig. 7 Ozone concentration as a function of number of saw-tooth electrodes

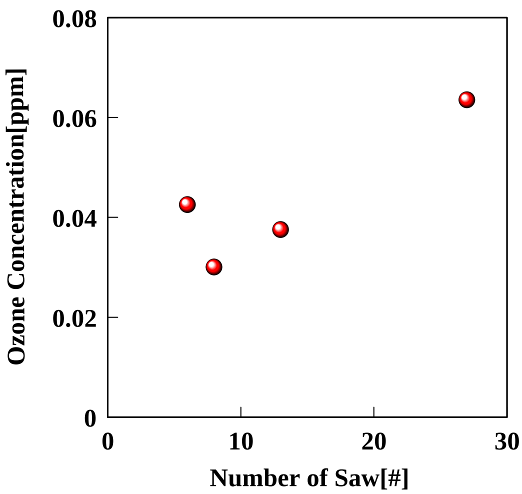


Fig. 8 Ozone concentration with 80% collection efficiency

are also shown in this figure. The collection efficiency is less than 80% though electrode of 6 saw-teeth is lowest the ozone concentration

In this study, the construction of ESP system was desired for ozone concentration under 0.06 ppm and collection efficiency over 80%. Therefore, the numbers of saw-tooth electrode are estimated with the discharge current condition for the collection efficiency over 80%. The ozone concentration characteristics with the discharge current condition for the collection efficiency over 80% are shown in Fig. 8. The discharge currents for 80% collection efficiency were 0.24 mA, 0.14 mA, 0.12 mA and 0.12 mA at 6, 8, 13 and 27 saw-teeth respectively. This figure shows that the ozone concentration of 8 saw-teeth was significantly lower than that of 6. This reason is considered that the discharge current at 8 saw-tooth electrodes is lower than that at 6.

From above mentioned, it is indicated that the optimum numbers of saw-tooth electrode are 8 in these experimental conditions.

4 CONCLUSIONS

In this study, the optimum electrode geometry in low ozone ESP was investigated. The electrode geometry changed the tip angle and the number of saw-tooth electrode. The results show the following:

1. In the characteristic of the saw tip angle, the ozone concentration is low like a pointed electrode.

2. From the observation result of the discharge luminescence in the saw-tooth electrode, the ozone concentrations increase with increasing discharge luminescence area.

3. In the characteristic of number of saw-tooth electrode, the optimum numbers of saw-tooth electrode are 8 in these experimental conditions.

REFERENCES

1. Andrew S. Viner, Phil A. Lawless, David S. Ensor and Leslie E. Sparks. Ozone generation in dc-energized electrostatic precipitator. IEEE Transactions on Industry Applications. Vol.28, No.3, May/June, 1992, 504-512.
2. A Yehia, M. Abdel-Salam, A. Mizuno. On assessment of ozone generation in DC coronas. J. Phys. D: Appl. Phys. 2000 (33): 831-835.
3. K. Takakura. Consideration for the Characteristics of Ozone Generation by Positive and Negative Corona Discharges. J. Electrostatics, 25, 2: 101-104, 2001(in Japanese).
4. Y. Ehara et. al. reduction of ozone generation in electrostatic precipitator. ICESP X 3C1, 2006.