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Effects of temperature and discharge parameters on ozone concentration of negative corona discharge

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Abstract: The relationship of the ozone generation and the heating power, corona wire surface temperature, discharge electrode and netting electrode was studied during the negative corona discharge. The experimental results showed that the ozone concentration reduced with applied voltage decrease. With heating power increase, the ozone concentration of unit current decreased at exponential rate and it almost change no longer over 0.40 W. Under given temperature, the lower the applied voltage was, the smaller the ozone concentration was; while under given applied voltages, only over 11 kV could decrease with the surface temperature increase. The ozone concentration decreased with the lengthening of corona wire, and could reduced to 10 ppb under experimental condition of 14.2 kV; it also decreased with the shortening of wire diameter, and could decrease 67% at best in the given condition. Moreover, it decreased with the increasing size of netting electrode mesh. At the anion current of 1.65 μA, the ozone concentration of $5.0 \times 5.0\ cm^2$ is only 41% of that of $3.3 \times 3.3\ cm^2$.

Keywords: ozone; negative corona discharge; anion current

Ozone generation during corona discharge was studied intensively in the past decades(Sigmond, 1993; Ohkubo, 1988; 1990). Ohkubo *et al*. studied the inhibition methods of ozone generation and distribution of ozone concentration by positive corona discharge. The result showed that ozone was concentrated near the corona wire and ozone concentration was reduced by the corona wired heating.

With the society developing, the quality of indoor climate was of great concern. Anion air cleaning equipment evoked even more attention. It not only cleaned air, but supplied higher concentration of anion that benefited human health(Jokl, 1989; Osborn, 1989). However, the air cleaning equipment in the market adopted the positive corona discharge, because ozone generation concentration produced by negative corona discharge was at least one more time than that of positive corona discharge (Ohkubo, 1988).

In order to obtain certain anion and reduce the ozone concentration indoor, a series of related researches had been done, such as corona discharge characteristics, the correlation between corona current and applied voltage and that between ozone concentration and corona current when heating the corona wire (Li, 1996).

1 Equipment and measurement

The experimental equipment was a quadrate box with length, width and height 63, 10 and 11 cm respectively(Fig.1). A small fan was put before the equipment and the airflow was adjustable. Ahead of the fan, there was an airflow meter that could offer airflow data. Negative corona discharge electrode and netting grounding electrode were put inside. The discharge electrode was made of 60/40 Ni-Cr alloys. Behind the netting grounding electrode, one compact sieve-style monitoring screen for anion was set, which was used for the measurement of the concentration of anion that pass through the former netting electrode.

The necessary voltage for corona discharge was supplied with a 20 kV secondary-export transformer. Alternating high voltage was supplied as negative voltage after half-wave commutated by diode and filtered by capacitor. The transformer was controlled by primary self-coupling booster. The power of coronawire heating adopted the1:1, 20kV insulated transformer 1:100 V positive direct current was added to the sieve-style monitoring screen. The ozone concentration was measured with Dasibi 1003-RS ultraviolet absorbed ozone monitor.

Corona wire was apart from netting grounding electrode about 2 cm, from monitoring screen about 8 cm. The ozone was sampled far away corona wire about 25 cm. The experiments were carried out under the

Foundation item: The China Scholarship Fund of the Ministry of Education; * Corresponding author indoor temperature. When experiment started, firstly started the fan and made it run smoothly. Then the ozone detector was started and the voltage was added to the monitoring screen 100 V exactly. After 5 minutes, one datum was obtained every 25 seconds and totally ten data were obtained. The mean was as the background of ozone concentration. When the corona wire heating experiment started, the supplied voltage was adjusted to the needed one and made it run smoothly. After 5 minutes, all parameters were measured. From the voltage that could cause corona discharge to that could cause spark discharge, one measurement was carried out every 1 kV. Every time, ten data of ozone concentration were obtained and the mean was as measured value. In the experiment the corona wire surface temperature is controlled between 40—100℃.

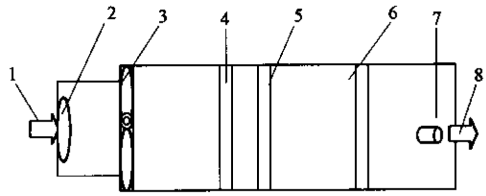

Fig.1 Diagram of experimental equipment
1. indoor air; 2. sharp edge orifice; 3. fan; 4. discharge wires; 5. ground screen; 6. ion collection screen; 7. sampling probe; 8. to hood

2 Results and discussion

2.1 The ozone concentration and applied voltage

At the room temperature, the electrodes space was 1.6 cm, the corona wire diameter was 0.1 mm, 0.2 mm, the mesh size of the sieve-style electrode was 3.3×3.3 cm^2.

In a given applied voltage, corona current increased with the shortening corona wire diameter. Therefore, the ozone generation will be affected by corona wire diameter. Fig.2 shows that under given applied voltages, the longer the corona wire diameter was, the lower the ozone concentration was, and vice versa. For example, under the voltage of 14 kV, when the wire diameter was 0.1 mm, the ozone concentration was 356 ppb; and when the wire diameter was 0.2 mm, it was 249 ppb. If the wire diameter was shorter, then the curvature was larger, the discharge was stronger, the energy was larger, and so the ozone concentration was higher. With the same corona wire diameter, the higher the applied voltage was, the larger the ozone concentration was. The ozone concentration was 74 ppb for the voltage of 11 kV and 497 ppb for the voltage of 15 kV at the corona wire diameter of 0.1 mm. The higher the applied voltage was, the larger the average energy of fast electron produced in the electric field was and the higher the ozone generation rate was. The result showed a positive correlation between the ozone concentration and the applied voltage.

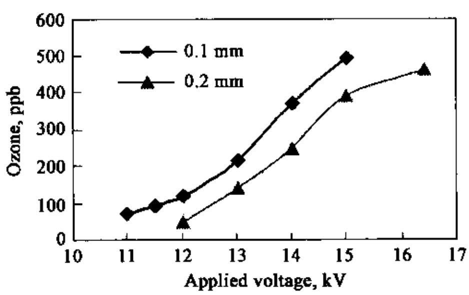

Fig.2 Relationship of ozone concentration with applied voltage

2.2 Ozone concentration and heating power

Fig. 3 shows the relationship between ozone concentration of unit discharge current and corona wire heating power under different applied voltages. When the ozone concentration of unit discharge current was chosen, the relationship between ozone concentration and heating power under the same corona current was obtained. The result showed that ozone concentration decreased at exponential rate with the increasing of corona wire heating power under the applied voltages. The difference of the three curves was obvious when heating power was low, then with its increase the difference would reduce. The change of ozone concentration was slightly when heating power was about 0.30 W. And the three curves were almost overlapped and the ozone concentration nearly reached the equilibrium when heating power was over 0.40 W. So in a certain range, the ozone concentration can be decreased through increasing the heating power.

2.3 Ozone concentration and corona wire surface temperature

Corona wire heating would increase the corona current and decrease the ozone concentration, however, the increase of corona current could result in the increase of ozone concentration (Casfle, 1969). The trade-off effect of corona wire heating and discharge current on the ozone generation both existed.

The relationship between ozone generation and surface temperature is given in Fig.4. The ozone

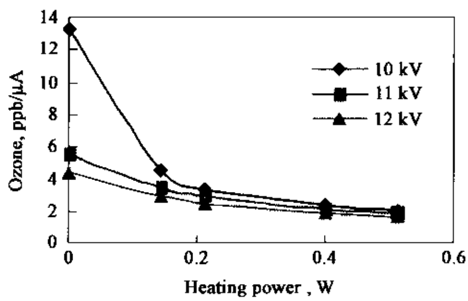

Fig.3 Relationship of ozone concentration and heating power

generation changed with the increasing of surface temperature under varied applied voltages. Under 10 kV, with the temperature increasing from 20℃ to 80℃, the ozone concentrations raised from 32 ppb to 55 ppb. Over 80℃ it began to decrease, and reduced to 46 ppb when the temperature reached 100℃. Of course the temperature rising could suppress ozone, but also make corona current stronger and ozone concentration higher. If the generated ozone was more than the suppressed, which led to the raising of ozone. Under 12—13 kV, the concentration of ozone was reduced with the temperature increasing. The higher applied voltage resulted in the increase of heating power, so enhanced the decomposing of ozone. Therefore, the concentration of ozone decreased with the temperature increasing.

Under given temperatures the higher the applied voltage was, the larger the ozone concentration was. When the temperature was 80℃, the ozone concentration was 55 ppb with applied voltage of 10 kV while it was 153 ppb with applied voltage of 13 kV. The latter was nearly 3 times of the former. It was due to that the higher voltage resulted in the stronger corona current, and so more ozone was generated.

2.4 Ozone concentration and discharge electrode sizes

The ozone concentration was related to the length and diameter of the corona wire. Provided lengths were 36 cm, 56 cm, and 96 cm; the diameters were 0.1 mm, 0.2 mm; and the mesh size of netting electrode was 5 × 5 cm^2.

Under different applied voltages, the relationship of the wire length and ozone concentration is shown in Fig.5. The longer the corona wire was, the lower the ozone concentration was. Under the applied voltage of 16 kV, ozone concentrations were 35, 110, and 229 ppb respectively with the length of 96, 56, and 36 cm. The longer the corona wire was, the evener the electric field was, the weaker the discharge current was, and the lower the ozone concentration was.

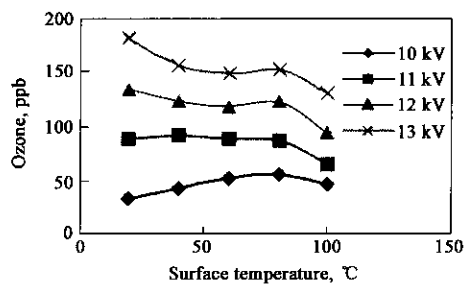

Fig. 4 Relationship of ozone concentration and temperature

The ozone concentration was also related to the diameter of the corona wire. Fig. 6 shows the relationship of ozone concentration and wire diameter under the given corona current. Ozone concentration rose with corona wire diameter lengthening, so reducing the corona wire diameter could decrease the ozone concentration. For example, with the corona current of 14 μA, it could be decreased 67% while the wire diameters were reduced from 0.3 to 0.1 mm. The larger the wire diameter, the smaller the curvature, so discharge was weaker and the corona current were smaller, and vice versa. Thus, under a certain corona current, when the wire diameter was shorter, the necessary corona voltage was lower and so was the ozone concentration.

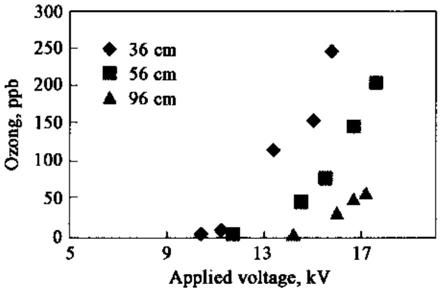

Fig.5 The change on ozone concentration with corona wire length

By calculating, we can also get the slope of 3.46 ppb/μA for a 0.3 mm wire, 2.23 ppb/μA for a 0.2 mm wire, and 1.23 ppm/μA for a 0.1 mm wire. The ozone concentration of unit discharge current showed a liner relationship with the wire diameter, according to the equation $y = 11.479x$ ($R^2 = 0.9955$). The trend agreed with that observed by Casfle *et al*. (Casfle, 1969).

2.5 Ozone concentration and netting electrode

The key technical parameters of anion air cleaner were the anion flow and ozone concentration, which were the yardstick of clean efficiency and improvement degree of indoor air quality. The size of netting electrode mesh influenced the

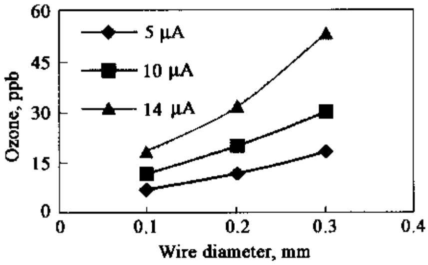

Fig. 6 Relationship between ozone concentration and wire diameter

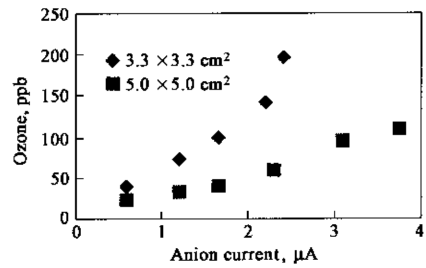

Fig. 7 Relationship of ozone concentration and sieve mesh size

corona current, anion flow and ozone concentration directly. Fig. 7 shows the relationship of ozone concentration and anion flow under different mesh sizes. The result illuminated that the ozone concentration decreased with the increasing of mesh size under a certain anion flow. For example, with 2.4 μA anion current, the ozone concentration of 5.0×5.0 cm^2 is only 41% of that of 3.3×3.3 cm^2.

It is because the larger the mesh size, the fewer the discharge section, the weaker the corona current and the lower the ozone concentration; but owning to the bigger size of mesh, the anion amount passing through the mesh is larger and that conducted to ground decreased, thus the anion current would not be influenced. Thus, by reducing the mesh size, not only the ideal anion current was obtained but also the ozone concentration was decreased.

3 Conclusions

The ozone concentration produced by discharge electrode increased with the rising of the applied voltage. Under given applied voltages, the longer the corona wire diameter was, the lower the ozone concentration was.

Under applied voltages, the ozone concentration of unit discharge current decreased at exponential rate with the increasing of heating power. In a certain range, increasing heating power could decrease ozone.

Under the same temperature, the lower the applied voltage was, the smaller the ozone concentration was. Under given applied voltages, only over 11 kV the ozone concentration could decrease with the surface temperature increasing.

Under given applied voltages, lengthening corona wire could decrease the ozone concentration; with a given corona current, shortening the corona wire diameter could also decrease it; for a given anion flow, enlarging the size of netting electrode mesh could decrease it, too.

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