Characteristics of Pulse Corona Discharge over Water Surface

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Abstract. Production of ozone and OH radical is required to advance the plasma chemical reactions in the NOx removal processes for combustion gas treatment. The corona discharge to the water surface is expected to induce the good conditions for the proceeding of the NO oxidation and the NO2 dissolution removal into water. In order to get the fundamental data of the corona discharge over the water surface, the positive and negative V-I characteristics and the ozone production were measured with the multi needle and the saw-edge type of the discharge electrodes. The pulse corona characteristics were also measured with some different waveforms of the applied pulse voltage. The experiments were carried out under the atmospheric pressure and room temperature. Both the DC and the pulse corona to the water surface showed a stable and almost the same V-I characteristics as to plate electrodes though the surface of water was waved by corona wind. The positive streamer corona showed more ozone production than the negative one both in the DC and in the pulse corona.

1. Introduction
The NOx treatment technology by non-thermal atmospheric plasma reactor has been developed with recent experimental and theoretical researches. It has been confirmed that production of ozone and OH radical are essential to the plasma chemical reactions in the NOx removal processes. [1],[3] Investigation of pulse corona reactor gave us a good result. We could simultaneously remove NOx and SOx in the combustion gas test plant. [2] DC corona discharge from the electrodes to water was expected to induce the good conditions for the NOx treatment reactor.

We designed a DC corona reactor with water and carried out NOx and dust treatment tests under various conditions with some different discharge electrodes. Positive streamer corona by saw-edge electrodes to the water surface showed the better results by our NOx removal tests.[4] The deNOx processes in the reactor was expected that ozone and radicals produced over the water surface promote the oxidation of NO to NO2 which easily dissolves into water. In addition the corona wind to the water surface helps the reaction. We determined the fundamental pulse corona characteristics by the wire-cylinder geometry of electrodes. The positive pulse corona with very short rise time showed the better discharge characteristics for the NOx treatment reactor. [5]
Our previous experiments suggested developing a new type of the reactor used pulse corona with water for the better NOx removal rate. [4]

2. Experiments
The model reactor was in the handmade plastic box with two types of discharge electrodes, one was multi-needle type and the other was saw-edge type as shown in Figure 1 and Figure 2. The discharge electrodes were placed above the water in the plastic box and a metal plate electrode in the water. Figure 1 shows the reactor geometry with multi needles for discharge electrode.

Pulsed high voltage was produced by a capacitor and a spark gap as shown in Figure 3. The rise time of applied pulse voltage was controlled by the inductance series connected to the spark gap. Every three shot of waveforms of the applied pulse voltage and discharge current were caught by a storage oscilloscope through a resistant divider and Rogowski coil. The pulse corona characteristics were measured with some different front waveforms of the applied pulse voltage.
3. Results and Discussion

3.1. DC corona characteristics
To compare the discharge mode to the pulse corona discharge, DC corona characteristics and produced ozone concentration were measured by the same reactor before the pulse corona experiment. Positive and negative DC coronas to water surface showed almost the same as the corona discharge to the metal plate electrode with the same air gap. Corona discharge induced corona wind to the water and some caves and wave appeared on the water surface in front of each needle top. It did not give much influence on spark occurrence. Positive corona produced much more ozone than negative at the same DC corona current. Corona current and spark voltage were not so much changed by the conductivity of water and the shape of metal electrode in the water. We got the better NOx removal rate in positive streamer corona than negative by the combustion gas treatment test with saw-edge type corona reactor both with and without water. [4]
3.2. Pulse corona characteristics

Figure 4 shows one of the typical waveforms of the applied voltage and current when the rise time of the applied pulse voltage was 53ns. Two peaks of current were measured only by the very short rise time of pulse voltage. The first peak current was proportional to the applied peak voltage as shown in Figure 5. The first current is estimated to be the charging into the capacitance formed by the geometry of two electrodes. The second peak current is estimated to be the corona discharge in air space. The pulse corona peak current to the water surface showed the similar V-I characteristics as the same geometry of metal electrode. The peak corona currents were much changed by the polarity and rise time of the applied pulse voltage, which are shown in Figure 6 and Figure 7. Positive applied pulse voltage with very short rise time less than 100ns is expected to induce the strong streamer corona and to produce effective ozone and the OH radical for the NOx treatment reactions. The pulse corona current also depends on the shape of the metal electrodes placed in the water and the conductivity of the water. Saw-edge electrode parallel placed over water surface gave the more corona current than the multi needle type with positive streamer discharge mode. It induces more production of effective radicals for the NOx treatment reactions.

4. Conclusion

Basic characteristics of pulse corona to the water surface were investigated with various applied pulse voltage. The positive corona by the applied pulse voltage with very short rise time is expected to induce the good condition for the NOx treatment reactions. Corona wind to the surface of the water did not so much decrease the spark voltage, but it helps to produce the OH and other effective radicals for NOx and SOx removal plasma reactions in combustion gas cleaning processes.

References

[1] S. Masuda and H. Nakao: IEEE Trans. IAS 26, p.374 (1990)
[2] L. Civitano, G. Dinelli and M. Rea: Proc. of Third Int. Conf. of Electrostatic Precipitation, (1987)
[3] M. Dors, J. Mizeraczyk, T. Czech and M. Rea: J. Electrostatics 45, p.25 (1998)
[4] T. Fujii, Y. Aoki, N. Yoshioka, M. Rea: Journal of Electrostatics, Vol.51-52, p.8(2001)
[5] T. Fujii, R. Gobbo and M. Rea: IEEE Trans. IAS, Vol.28, No.1, p.98 (1993)