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EXPERIMENTAL STUDY ON ELECTROSTATIC PRECIPITATION WITH SPRAYING CORONA DISCHARGES

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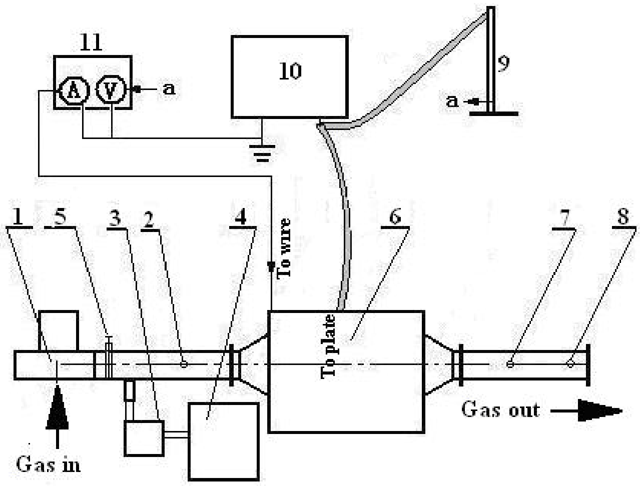
ABSTRACT
A simulative device was employed. The corona onset saturation, the V-I characteristics and the precipitation efficiency were researched and compared between spraying negative corona discharges and dry negative corona discharges. The experiments shown the precipitation efficiency of spraying negative corona discharges reached to 28% higher than that of dry corona discharge (from 78.2% to 84.2%), under the conditions of the same high voltage and gas flow rate. The new discharge characteristics and precipitation principle were analyzed and discussed. The comparing between spraying negative corona discharges and dry negative ones shown that spraying negative corona discharge is more suitable for removal of particle contamination. The spreading corona plasma of spraying positive corona discharges plays a more important role for purifying the spraying circulating water.

INTRODUCTION

The electro-hydrodynamic (EHD) spraying was formed on jets of water which was connected with high voltage and flowed vertically. There were many reports about studying on the spraying mode and character. Although a Charged droplet scrubber according to the principle of EHD spraying could effectively catch particle contamination, the difficulty of HV insulation for supplying water system couldn't be resolve and electrostatic precipitation with corona discharges didn't be formed (Lear C.W., Krieve W.F. and Cohen E 1975). If the discharge electrodes of traditional precipitator were grounded and the collecting electrodes were connected to a high voltage, the difficulty of HV insulation was avoided (Xu Dexuan, Li Jie, Wu Yan, et al. 2003). By this way, spraying corona discharges were formed under electric field on the water surface. Spraying corona discharges consist of electro-hydrodynamic spraying and water electrode corona discharges. The study on mechanism and character of spraying corona discharges was reported rarely (Moon Jae-Dik, Kim Jin-Gyu and Lee Dae-Hee 1998) and the study on electrostatic precipitation with spraying corona discharges was introduced in the paper.

1 EXPERIMENTAL APPARATUS



1. Fan 2. Front sampling hole 3. Dust generator 4. Air compressor 5. Valve 6. Precipitator 7. Rear sampling hole 8. Anemometer measuring hole 9. HV probe 10. HV power supply 11. Controller

Fig. 1 Experimental apparatus of electrostatic precipitation with spraying corona discharges

The experimental apparatus was shown in Fig.1. The wire-plate configuration was employed in the precipitator 6, and the discharged electrodes were grounded. Electrostatic precipitation with spraying corona discharges was carried out. When the plate electrodes were connected to positive HV, negative corona discharges were produced under the induction effects of the discharge electrodes, and electrostatic precipitation with spraying negative corona discharges was formed. Contrarily, when the plate electrodes were connected negative HV, electrostatic precipitation with spraying positive corona discharges was formed. The space between discharge electrode and plate electrode was 30 mm and the curvature radius of the discharge wire was 0.2 mm. In the precipitator, the plate electrodes were connected to the HV power supply through cable. High voltages were measured by the HV probe 9. The controller 11 could adjust high voltage value in the precipitator. The values of both current and voltage under spraying corona discharge were respectively shown on the ammeters. The indoor air flow was imported in the device by the fan 1. The dusts were dispersed into the air flow by the compressor 4 and the dust generator, and the simulative flue gas was produced. In the experiment, we adopted the sampling technique with equal flow rates inside and outside the sampler, the dust concentrations before precipitator were measured in the front sampling hole 2 using weight method, while the concentrations after precipitator were measured in the rear hole 7, then the precipitation efficiencies could be calculated. The flow rates of the flue gas were measured in the measure hole 8 and the valve 5 could adjust the flow rates.

2 EXPERIMENTAL RESULTS AND DISCUSSIONS

2.1 Corona Onset State of Spraying Negative Corona Discharges

In the electrostatic precipitator as Fig.1, the discharge electrodes were vertical and grounded. When the spacing between grounded wire electrodes and HV plate electrodes was 30 mm, the corona onset voltages were respectively measured under supplying water to wire electrodes (spraying corona discharges) and no supplying (dry corona discharges). The experiments have demonstrated that the onset voltage of dry negative corona discharges was 12.5 kV and that of spraying negative corona discharges was 7 kV. The onset voltage of spraying corona discharges was much lower than that of dry corona discharges.

When the positive HV on the plate electrode was high enough, strong electric field was produced near the wire electrode. Therefore the instability of water surface was increased and the Taylor Cones were formed (Jaworek A, and Krupa A. 1999). Different from the Taylor Cone on horizontal water surface, the protrusion height of the Taylor Cones on vertical water surface was higher and their peaks were directed outwards and downwards, because the gravity was perpendicular to the electrostatic force. With the increasing of high voltages, the Taylor cones extended outwards and downwards, and spraying of the water was produced. Therefore the spacing between wires and plates was shortened and the curvature radius of the discharge points reduced. The corona onset electric field (Ec) is determined by Peek formula under electrostatic force

$$Ec = 3100\ fd[1+k/(dr)^{1/2}]\ (kV/m)$$

Where d is the relative density of the gas, r is the curvature radius of discharge points; $k=3.08X10^{-2}(m^{1/2})$; f is the roughness coefficient of discharge points. When the voltage was lower, a very strong electric field was produced near the peaks of Taylor Cones, which extend outwards and downwards from the discharge electrode and r was very small. The electron avalanches and gas ionizations were formed under a lower high voltage. Therefore, the corona onset voltage of spraying corona discharges was obviously lower than that of dry corona discharges.

2.2 V-I Character of Spraying Negative Corona Discharge

The V-I characteristic curves of spraying negative corona discharges are shown in Fig.2.

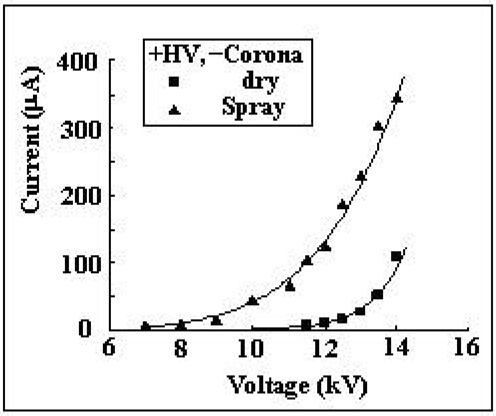


Fig.2 V-I characteristic curves of spraying negative corona discharges vs. dry negative ones

Under the same experimental condition, the V-I characteristic curves of dry negative corona discharge are shown in Fig.2 too. The experiments have demonstrated that the currents of spraying corona discharge were higher than that of dry corona discharges under the same voltages.

When voltage was higher than the onset voltage of spraying negative corona discharge and reached the normal operation voltages, with the strengthening of electric field, the spraying mode of cone-jet-corona on the water surface developed into the spraying mode with multi-jet-corona (Noymer D.and Garel M. 2000). At this time, the multi-jet with a diameter of several tens μm on the water surface strengthened the corona discharges. Furthermore, a lot of droplets with a diameter of several tens μm and large numbers of charges strengthened the inter-electrode currents. Therefore, the currents of spraying corona discharges were higher than that of dry corona discharges.

2.3 Precipitation Efficiency of Spraying Negative Corona Discharge

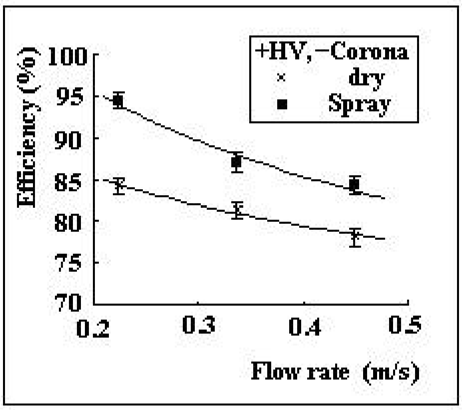


Fig.3 Precipitation efficiency of spraying negative corona and dry ones

When negative HV was 12 kV (average electric field was 4000V/cm) in the spraying negative corona discharges, the precipitation efficiency was measured under different flow rates in the electric field. The measuring results were shown in Fig.3. When the flow rate in the electric field was 0.448 m/s, the precipitation efficiency of dry negative corona discharge was 78.2%, while the precipitation efficiency of spraying negative corona discharge was 84.2%. Therefore, the precipitation efficiency of spraying negative corona discharges increased 28% than that of dry negative corona discharges.

The reason that the precipitation efficiency of spraying negative corona discharges was higher than that of dry negative corona discharges was as follows. The spraying negative corona discharges not only have the same mechanisms of dust charging and electrostatic collecting as in dry negative corona discharges, but also a lot of spraying droplets with many charges and a diameter of few tens μ m. At first the droplets ejecting from the discharge electrodes were charged by the electrostatic induction, then were charged again by negative ions and electrons in the strong electric field near discharge electrodes. The highly charged droplets flew quickly to the plate electrodes and had efficient electrostatic agglomeration and dynamic agglomeration for the fine dusts in flue gas. Therefore, the precipitation efficiency was improved effectively in the spraying corona discharges.

2.4 Comparing between Spraying Positive Corona Discharges and Spraying Negative Corona Discharges

When the positive or negative voltage was 12 kV, the precipitation efficiency was compared under different flow rate. The Fig.4 demonstrated that the precipitation efficiency was increased from 82.3% of spraying positive corona discharges to 84.2% of spraying negative corona discharges, which means that the precipitation efficiency of spraying negative corona discharges increased 11% than that of spraying positive corona discharges, when the opening flow rate was 0.448 m/s.

The fact of lower precipitation efficiency of spraying positive corona discharges is attributed to expanding corona region. When the high voltage was increased continually above 12 kV in spraying positive corona discharges, a purple bright region was produced near the discharge electrode. With the increasing of high voltage, the brightness of bright region was intensified and the range was expanded. Before spark discharges occurred, the range of the bright region expanded to the midpoint of the space between wire and plate electrodes. Primary analysis for the phenomena indicated that the purple bright region was produced by corona discharge of a large number of highly charged droplets. Therefore, under relative high voltage, there was the expanding trend of corona region near discharge electrode in spraying positive corona discharges. The expanding of non-thermal plasma reduced the particle charges and the precipitation efficiency was lowered (Xu Dexuan et al. 2003). However with the increasing of voltage, the phenomena that corona plasma expanded was not observed in spraying negative corona discharges. So the precipitation efficiency of spraying positive corona discharge was lower than that of spraying negative corona discharges. Comparing with spraying positive corona discharges, spraying negative corona discharges were more suitable for removing particles from flue gas.

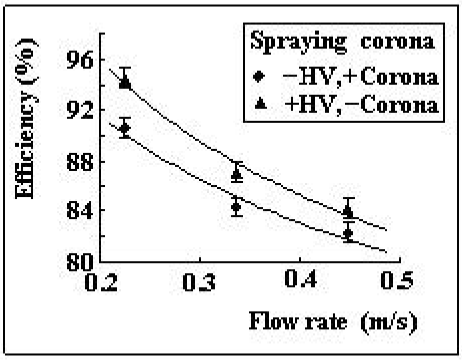


Fig.4 Precipitation efficiency of spraying negative and positive corona discharges

The experiments on the spraying corona discharges with indigo solution demonstrated that the expanding corona plasma region had great functions of decolorization (Wu Yan, Xu Dexuan, Li Jie, et al. 2001). It showed that spraying positive corona discharge could deal with spraying circulation water effectively.

2.5 Cleaning Function on Electrodes in Spraying Corona Discharges

In spraying corona discharge, the spraying of water on the surface of discharge electrodes was produced continuously. So discharge electrodes could be cleaned during the operation period. The function could not be realized in traditional electrostatic precipitator because of high voltage on the discharge electrodes.

When the discharge electrodes were cleaned by spraying water, the high voltage plates were cleaned too. In the electrostatic precipitation with spraying negative corona discharges, lots of spraying droplets were charged from discharge electrodes, and they were charged further when they flew through the inter-electrode region. Finally, the droplets bombed to the plate electrodes and formed a down flowing water membrane. Therefore, the discharge electrodes and plate, when the precipitator was operating.

In order to observe and validate the cleaning function of plate electrodes in spraying corona discharges, a experimental apparatus of spraying negative corona discharge without flue gas was employed. The space between discharge electrode and plate electrode was 150 mm and the HV is 55 kV. A thin layer of adhesive wet fly ash was smeared on the plate electrode before the operation. The results are shown in Fig.5 after 3 minutes discharge. The dark area on plate electrode was thoroughly cleaned by spaying water. Obviously, the width of cleaned plate electrode was larger than the space between discharge electrode and plate electrode.

At the top of plate electrode there was a small white area, which was not cleaned. In electrostatic precipitator with spraying corona discharges, the top of discharge electrode was higher than that of plate electrode because of HV insulation. So the white area of plate electrode could be effectively cleaned too.

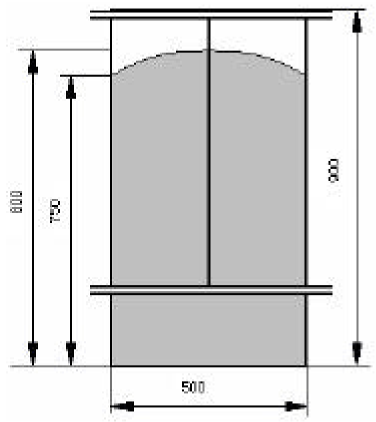


Fig. 5 Cleaning effects of charged droplets on plate electrode

3. CONCLUSIONS

i.) For the influence of electro-hydrodynamic spraying, the corona onset voltage of spraying corona discharges was lower than that of dry corona discharges.

ii.) For the effect of lots of highly charged droplets, the current of spraying corona discharges was higher than that of dry corona discharges.

iii.) The electrostatic agglomeration and dynamic agglomeration of charged droplet were strengthened in spraying negative corona discharges, so the precipitation efficiency of spraying negative corona discharges was higher than that of dry negative corona discharges.

iv.) Because of expanded corona plasma in spraying positive corona discharges, the precipitation efficiency of spraying positive corona discharges was lower than that of spraying negative corona discharges.

v.) Spraying negative corona discharges were more suitable for removing particles from flue gas.

vi.) Spraying positive corona discharge could deal with spraying circulation water effectively.

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