Dust particles motion in back discharge

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Abstract. The back discharge is a type of discharge that takes place in the electrostatics precipitation process, especially in coal-fired power plants for coal of low content of sulfur. This type of discharge takes place in the presence of corona discharge and occurs on an electrode covered with a high resistivity dust layer. The breakdown of dielectric layer causes an increase in the discharge current and re-entrainment of dust particle from collection electrode into the flowing gas. The investigations of the motion of dust particle emitted from the collection electrode are presented in this paper. Additionally, acrylic powder layer placed between a mica plate with a small pinhole and the plate electrode were also used in the experiments in order to generate repeatable back discharge. An effect of back discharge on the collection efficiency in the electrodes system was also presented.

1. Introduction

The back discharge is a type of discharge that takes place in the electrostatic precipitators, especially in coal-fired power plants when low sulfur coal is burned. This type of discharge takes place in the presence of corona discharge. The charge emitted by the discharge electrode accumulates on the surface of dielectric layer and causes an increase of the magnitude of electric field within this layer. The accumulated charge decreases also the magnitude of electric field in the interelectrode space. The electric field within the layer increasing due to the accumulated charge leads to the breakdown of this layer. The breakdown causes an increase of the discharge current and re-entains dust particles from collection electrode into the flowing gas. The process leads to back-discharge onset on plate electrode covered with a high resistivity dust layer. The results of investigation of back discharge are presented in the literature [1-4], but the motion of dust particles re-emitted from the collection electrode during the back discharge was hitherto not presented. This paper presents the results of visualization of dust particles motion in the back discharge from fly-ash dust layer. The dust has been assembled from the last section of electrostatic precipitator in a power station in Gdansk. Additionally, acrylic powder layer placed between a mica plate with a small pinhole and the plate electrode was used in the experiments in order to generate repeatable back discharge. An effect of back discharge on the collection efficiency of a precipitation system was also investigated.

2. Experimental set-up

Schematic of experimental stand are shown in figures 1 and 2. The back discharge was generated in a needle-to-plate and multi-needle-to-plate electrode geometries with fly-ash layer deposited at the collection electrode. For better visualisation of particle motion during the back discharge, the research
was also carried out in a model system with mica layer with pinhole and acrylic powder with spherical particles of average diameter 40 μm. The resistivity of powder is higher than 10^{14} \, \Omega m. This system allows getting repeatable back discharge.

The motion of dust particles emitted from fly-ash layer was recorded by CCD camera. The motion of particles was caused by the electric field between the electrodes. During the discharge, gaseous ions flow from the discharge electrode (needle) to the interelectrode space along the lines of the electric field. The ions drag gaseous molecules and cause the motion of the gas. However, the ionic wind does not blow out the fly-ash particles from the layer on the collection electrode [5].

It was observed in the model system, that acrylic powder erupted from the opening in the mica plate moved in the direction of the discharge electrode when the high voltage was switching on. The erupted particles have got a charge opposite to the discharge electrode. When the fly-ash layer was placed on the collection electrode, the particles were emitted from the layer just after the the breakdown streamer or back-arc discharge was started. The schematic of the multi-needle-to-plane electrode system, which was used in the investigation of the influence of back-discharge on the collection efficiency, is presented in figure 2.

3. Results
Schematic diagram of charge distribution within the layer and in the interelectrode space in the needle-to-plane geometry is presented in figure 3. A photograph showing the eruption of acrylic powder is presented respectively in figure 4. The acrylic powder burst out through the opening in the mica plate and moved in the direction to the discharge electrode (needle). During this motion, the trajectories of particles were changed, and turned back to the collection electrode. The acrylic particles emitted from the opening carried a positive charge, and during their flow to the discharge electrode of negative polarity, they were recharged negatively by negative ions flowing from the discharge electrode. A sequence of photographs showing a development of the back arc discharge with simultaneous eruption of acrylic powder is presented in figure 5. The back arc discharge started at a supply voltage of about -20 kV, when the high voltage was switched on. The first photo in figure 5 shows the electrode system prior to the discharge. On the second photo, the breakdown streamers are presented. The back arc discharge with intense eruption of acrylic powder (bright shadow bottom - right) is visible on the third photo. The next photo presents how the eruption of acrylic powder continues. The process of eruption ceases on the last two photos because whole the dust close the pinhole had erupted in the first tens of milliseconds.

The back discharge in the electrode system with fly-ash layer was also investigated. The schematic diagram of charge distribution in back discharge for collection electrode covered by fly-ash layer is presented in figure 6. The fly-ash was dried in the temperature of 240°C by the period of 2 hours before the measurements. The eruption of fly-ash particles during the breakdown streamers of
**Figure 3.** Schematic diagram of charge distribution in the model system

**Figure 4.** A photograph of acrylic powder eruption in the model system for -10kV

**Figure 5.** A sequence of photographs presenting development of back arc discharge with simultaneous eruption of acrylic powder (Supply voltage –20 kV, ballast resistor 7MΩ). Repetition frequency 25frame/s.

**Figure 6.** Schematic diagram of charge distribution in back discharge with a collection electrode covered by fly-ash

**Figure 7.** A photograph of fly-ash particle eruption during the breakdown streamer of back discharge for –16kV.
back discharge is presented in figure 7. After the breakdown of fly-ash layer and breakdown streamer or back arc discharge ignition, the fly ash particles were emitted from crater formed in the layer. The fly-ash particles emitted from the crater have the charge of polarity opposite to discharge electrode. By this way, the back-discharge decreases the collection efficiency. The results of measurement of an effect of fly-ash layer thickness, the supply voltage, and gas velocity on the collection efficiency in a multi-needle-to-plane electrode system are shown in figure 8.

![Figure 8](image_url)

The collection efficiency was decreased with an increase of the fly-ash layer thickness because the charge accumulated on the fly–ash surface caused a decrease of the magnitude of the electric field in the interelectrode space. For the layer of thickness of 2mm and supply voltage higher that 16kV the breakdown streamer or back-arc discharge occurred, and the collection efficiency dropped because the fly-ash particles were emitted during the crater was formed. The second mechanism of reduction of collection efficiency is a charge elimination by the opposite ions from breakdown points of the dust layer.

4. Summary
It was shown in the paper that the ions drag gaseous molecules and cause the motion of the gas. However, the ionic wind does not blow out the fly-ash particles from the layer on the collection electrode. For better visualization of particle motion during the back discharge, experiments in a model system consisting of a mica plate with pinhole placed on an acrylic powder layer were carried out. This system allowed getting repeatable back discharge. The motion of dust particles emitted from fly-ash layer was caused by the electric field between the electrodes. In the model system, the acrylic powder erupted from the opening in the mica plate and moved towards the discharge electrode. After the eruption, the particles of acrylic powder have got a charge opposite to that of the discharge electrode. For fly-ash layer on the collection electrode, the fly-ash particles were emitted at the moment breakdown streamer or back-arc discharge has started and the crater was formed. The presented results of visualization provide information of the mechanisms of the fly-ash particles emission during the crater production in back discharge.

5. References
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