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# VISUALIZATION OF DUST PARTICLES MOTION IN BACK DISCHARGE

The back discharge takes place in an industrial electrostatic precipitation process, especially in coal-fired power plants whose operation is based on low-sulfur coal. This type of discharge occurs simultaneously with corona discharge on an electrode covered with a high-resistivity dust layer. The charge that accumulates on the dielectric layer surface is responsible for an increase in the magnitude of electric field within the dielectric layer and a decrease in the magnitude of electric field between the electrodes. The breakdown of dielectric layer increases the discharge current and the re-entraining of dust particles from collecting electrode into the flowing gas. The motion of dust particles emitted from the collecting electrode and an air flow pattern were investigated. Additionally, acrylic powder layer placed between a mica plate with a small pinhole and the plate electrode was also used in the experiments in order to generate a repeatable back discharge.

## 1. INTRODUCTION

The back discharge occurs simultaneously with the corona discharge on an electrode covered with a high-resistivity dust layer. The results of investigation of the back discharge can be found in an available literature [1]–[3], but the motion of dust particles re-emitted from the collecting electrode during the back discharge have not been given. This paper presents the results visualizing dust particles motion during the back discharge in a fly-ash dust layer. The dust has been collected from the collecting electrode of the last electrofilter in a power plant station in Gdańsk. A model system with acrylic powder has been used in the investigation for a better visualization of particle motion. The acrylic powder particles have a spherical shape and the diameter of about 40 μm. Bulk density of acrylic powder is 2.52 g/cm$^3$, its resistivity in a packed bed is higher than $10^{14}$ Ωm and a relative permittivity reaches 4. A mica layer with a pinhole and acrylic powder layer enabled us to achieve repeatable back discharge. A pattern of gas flow around the system of electrodes was also investigated.

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During the corona discharge the charge is accumulated on the dielectric surface which increases the electric field strength in dielectric and decreases the electric field strength in the interelectrode region. At a sufficiently great strength of electric field within the dielectric layer, this layer was broken down and conducting channels were created through the layer. The material of the layer and the surrounding air were ionized and ions of the polarity opposite to that of the discharge electrode were re-emitted into the space between the electrodes. During the back discharge the dust from collection electrode was re-emitted into the flowing gas, which can lead to a decrease in the efficiency of electrofilter.

## 2. EXPERIMENTAL SET-UP

The schematic diagram of the experimental stand is shown in figure 1. The back discharge was generated in a needle-to-plate electrode geometry. The discharge electrodes were placed in a channel made of acrylic glass with the following dimensions: 560 mm in length, 100 mm in width and 80 mm in height. The plate electrode was covered with the dielectric layer.

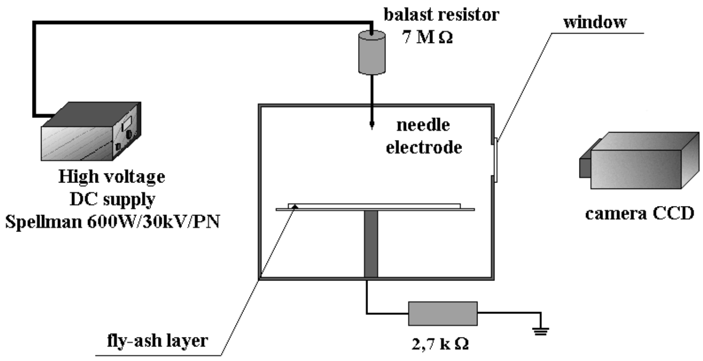



Fig. 1. Schematic diagram of the experimental set-up

The corona-discharge electrode was made of a stainless steel needle, 1.5 in diameter. Its tip is conically sharpened and the apex angle reaches 30°. The counter (collection) electrode was made of stainless steel sheet with the following dimensions: 560 mm in length, 100 mm in width. The distance between the electrodes was 20 mm. The discharge electrode was supplied from the high-voltage DC source SPELMAN 600W/30kV/PN. A ballast resistor connected in series with the discharge electrodes was used to stabilize the discharge current. Before the experiments the fly ash was dried at a temperature of 240 °C for 2 hours. The voltage on the discharge electrode was measured by a high-voltage probe Tektronix P6015A. Two glass windows, each of 52 mm in diameter, made in a channel sidewall allowed taking photographs of dust and air motion during the back discharge. The photographs were taken with digital camera NV-GS400 Panasonic with additional lens RAYNOX MACROSCOPIC LENS Model M-250. The light knife was made by the source of light (150 W power) with optical system collimating the light beam in the interelectrode space. In order to generate a repeatable back discharge, in the experiments the mica layer with pinhole and acrylic powder produced by Spofa-Dental-Praha were used.

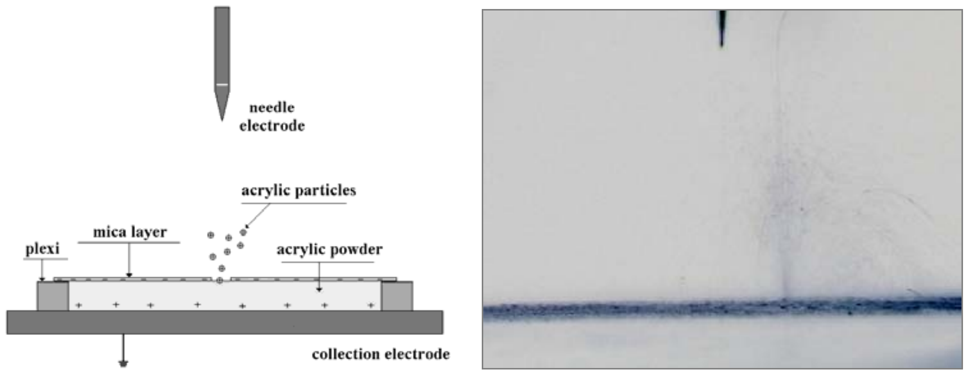
## 3. RESULTS

The gas motion between the discharge electrode and the collecting electrode covered with a fly-ash layer was visualized. Cigarette smoke was used for this visualization. A schematic diagram of the system of electrodes and the photographs of a smoke indicating flow pattern in the space between the electrodes at 16 kV supply voltage are shown in figure 2. In figure 2b with the voltage switched off, the smoke freely flows within the chamber. In figure 2c, the smoke is only visible at the left-hand side of the photograph. There is no smoke beneath the discharge needle because a ionic wind blows the particles off the interelectrode space. The motion of negative ions flowing from the discharge electrode to the collecting electrode provokes the motion of the smoke particles. Lack of visible smoke in the space between the electrodes at the voltage of 16 kV (figure 2c) was caused by taking away smoke particles by a ionic wind. Additionally, the phenomenon of charging smoke particles in electric field takes place (mean particle diameter is about 1 μm [4]), and the smoke particles are precipitated on the collecting electrode. The phenomenon of charging the smoke particles distorted the view of gas flow caused by a ionic wind. From the analysis of the photographs presented it can be concluded that the gas flows in the interelectrode space from a needle (discharge electrode) along the electric field lines to the collecting electrode.


(a) b) c)

Fig. 2. Schematic diagram of electrodes (a)
and visualization of gas flow with smoke at 0 kV (b) and 16 kV (c)

For a better visualization of particle motion during the back discharge, the experiments were carried in the system of the collecting electrode covered with a 2 mm layer of acrylic powder. The layer of acrylic powder was next covered with mica plate with a small hole of 0.6 mm in diameter. This system allows a repeatable back discharge, because the point of discharge was strictly defined by the hole in the mica plate. The crater of the back discharge was, therefore, always in the same place. Schematic diagram of charge distribution in the system and visualization of acrylic powder eruption were presented in figure 3. The acrylic powder escaped from the electrode by the opening in the mica plate and moved in the direction to the discharge electrode (needle). During this motion the trajectories of the particles were changed, and turned back to the collecting electrode. The acrylic particles emitted from the opening were positively charged and during their flowing to the discharge electrode of negative polarity they were recharged negatively by negative ions flowing from the discharge electrode.




a) b)

Fig. 3. Schematic diagram of charge distribution (a)
and visualization of acrylic powder eruption at –10 kV in model system (b)

The start of the back arc discharge with eruption of acrylic powder was presented in figure 4 as the sequence of photos. The back arc discharge started at the voltage of about –20 kV. The electrode system before the discharge is visible in the first photo in figure 4. In the second photo, the breakdown streamer is presented. The back arc discharge with intense eruption of acrylic powder is visible in the third photo. The fourth photo presents the continuation of acrylic powder eruption. We are not able to observe the acrylic powder eruption in the fifth and sixth photos, because whole dust has erupted by the opening in the mica plate.

The back discharge in the electrode system with fly-ash layer was investigated. The schematic diagram of the charge distribution in back discharge for collecting

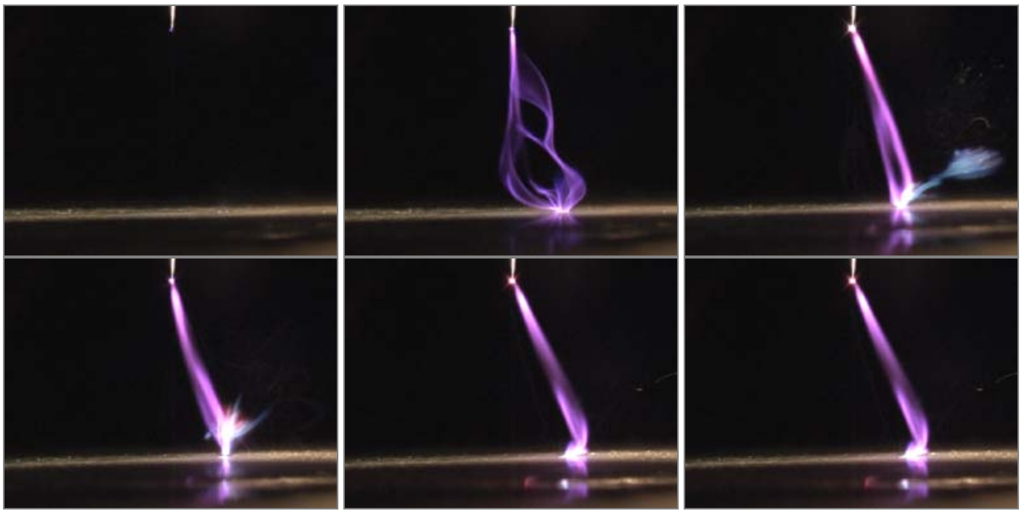
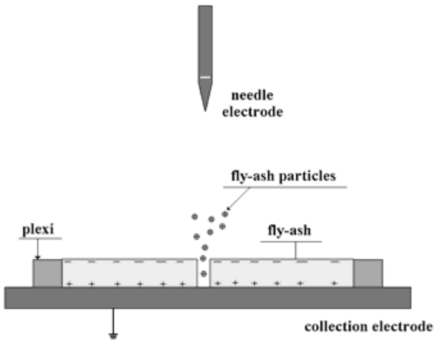


Fig. 4. The start of the back arc discharge with eruption of acrylic powder at –20 kV (repetition frequency of 25frame/s)




a)

b)

Fig. 5. Schematic diagram of the charge distribution in back discharge (a) and fly-ash particle eruption in the breakdown streamer of back discharge at –16 kV (b). The collecting electrode was covered with the layer of fly-ash

electrode covered with fly-ash layer was presented in figure 5a. The fly-ash was dried at the temperature of 240 °C for 2 hours before the measurements. The start of the breakdown streamer of the back discharge and the eruption of fly-ash were shown in figure 5b. After the breakdown in a dielectric layer and the arc-discharge firing, the fly ash particles are emitted from the crater on the collecting electrode. The charge of the fly-ash particles emitted from crater and the charge of the discharge electrode were oppositely polarized.

## 4. SUMMARY

The visualization of the motion of the ionic wind in interelectrode space was presented for the needle-to-plate electrode geometry. The gas moves in an interelectrode space from the needle (discharge) electrode to the collecting electrode according to the electrical field distribution. The ionic wind does not blow away the fly-ash particles from the layer on the collecting electrode. For a better visualization of particle motion during the back discharge, the research was carried out in a model system with mica layer with pinhole and acrylic powder. This system allows repeatable back discharge. The motion of dust particles emitted from the fly-ash layer the collecting electrode was investigated as well. The motion of particles was due to the electric field between the electrodes. In the model system, an acrylic powder erupted from the opening in the mica plate and moved in the direction of the discharge electrode. The charge of the particles of acrylic powder and the charge of the discharge electrode after eruption were oppositely polarized. The fly-ash particles were emitted from the fly-ash layer on the collecting electrode at the start of breakdown streamer or back-arc discharge during the crater formation. The visualization results presented enable us to discuss about the reasons for the motion of particles in back discharge.

## REFERENCES

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## WIZUALIZACJA RUCHU PYŁU W WYŁADOWANIU WSTECZNYM

Wyładowanie wsteczne występuje podczas użytkowania elektrofiltrów w przemyśle wykorzystującym niskozasiarczony węgiel. Wyładowanie wsteczne pojawia się wówczas, gdy elektrodę osadczą pokrywa warstwa pyłu o dużej rezystywności. Gromadzący się na powierzchni warstwy ładunek powoduje wzrost natężenia lokalnego pola elektrycznego w obszarze warstwy dielektrycznej oraz spadek natężenia pola elektrycznego w przestrzeni międzyelektrodowej. Wskutek przebicia warstwy dielektrycznej wzrasta natężenie prądu wyładowania oraz emisja pyłu zebranego na elektrodzie zbiorczej do przepływającego powietrza. Przedstawiono ruch cząstek pyłu emitowanych z elektrody zbiorczej oraz strukturę przepływu powietrza wokół elektrody wyładowczej. W badaniach wykorzystano również układ modelowy, w którym warstwą dielektryczną była płytka miki, a zamiast pyłu z elektrofiltru wykorzystano pył akrylowy.