Performance Evaluation of the Wire to Multicylinders Electrostatic Precipitator with PVC Powder

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Abstract **-**In this study, a series of experiments were conducted to evaluate the performance of a wire-multicylinder electrostatic precipitator (ESP). The experiments were carried out with polyvinyl chloride powder «PVC» of different diameters and for negative Direct Current (DC) supply voltages and a constant gas velocity. Experimental setup and measurement methods are described. Experimental results were compared to the previous study. The results obtained made it possible to determine the effect of particle diameter and their properties on the collection efficiency of ESP wire - multicylinder. As the applied voltage increases, the particle collection efficiency increases. The resistivity of the particles plays an important role in the performance of the ESP; however, as the diameter of the PVC particles is greater, the higher collection efficiency has been obtained.

Keywords **-**wire-multicylinders electrostatic precipitator (ESP), polyvinyl chloride powder «PVC», collection efficiency.

I. INTRODUCTION

Due to the vast industrial and urban development, which affected positively the standard of life of human beings, enormous types of wastes with tremendous quantities were generated as a side effect of this development. Particulate emissions are definitely among the industrial waste that needs control. Particulate matter is described as dispersed airborne solid and liquid particles that can be distinguished not only on the basis of chemical composition but also with respect to size; their diameter varies from 0.005 µm to 100 µm. It can alone or combined with other pollutants pose serious health problems especially to people who are subjected to continuous exposure [1].

Several systems and processes have been used for the control of particulate emissions. Those include settling chambers, cyclones, fabric filters, wet scrubbers, and electrostatic precipitators (ESPs). All systems share high collection efficiency. Electrostatic precipitators are one of the most promising ways of controlling air pollution caused by industrial plants (smoke, fumes, and dust). Compared to other treatment devices, an ESP offers high collection efficiency even for ultrafine particles (that exceed 99%), low pressure drop and low operating costs. Another important advantage is that it can be operated with very small energy consumption [1,2].

The basic principles governing the operation of electrostatic precipitators are relatively straightforward, and hence are well described in the literature and can be found in Robinson [3] and Rose [4]. Fundamentally, an ESP eliminates the dust particle from the polluted gas by charging the particles with ions generated from a corona discharge. The charged particles migrate towards the collecting electrodes under the effect of the electric field created by the potential difference between the high voltage and the grounded electrodes [5].

The performance of the ESP depends on the temperature and humidity of the flue gas, magnitude and polarity of applied voltage, as well as on the dust particles characteristics including particles size and resistivity [6].

In this context, experimental research on the precipitation of solid and liquid particles with the ESP has become a matter of vital interest. Despite the great number of investigations, theoretical [7–9] and experimental [10, 11],

reported in the literature, there is still some effort to be made to find an optimal geometry of the discharge electrodes for the precipitation of fly ash differing in physicochemical properties [5].

The objective of the study reported on in this paper was to investigate the precipitation efficiency for the fly ash emitted from industrial processes of construction of pipes (polyvinyl chloride "PVC" powder). The experiments were performed with a wire to multicylinder ESP under laboratory conditions. The results are compared with results of incense smoke in previous study [12].

II. EXPERIMENTAL SETUP AND METHODS

II.1. DESIGN OF THE PRECIPITATOR ELECTROSTATIC

The ESP used in the present study is shown in "Fig.1. The designed ESP includes an iron wire electrode (1) (0.25 mm diameter and 520 mm length) and five grounded cylinder electrodes.

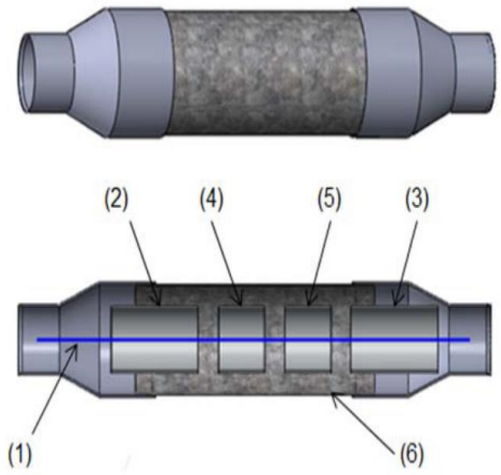

Fig. 1. Descriptive (schematic) of the wire to multicylinder electrostatic precipitator [12].

The wire electrode is supplied with a high voltage power supply to produce a corona discharge. The collecting unit has two types of cylinder electrodes: interior electrodes made of aluminum (2 mm thick) placed one beside the other with 20 mm spacing, each two have the same height (the two cylinders on the sides (2) & (3) have a height of 85 mm and the two ones in the middle (4) & (5) have a height of 45 mm). The second type of cylinders is the main grounded electrode (6) made of stainless steel (100 mm diameter, 245 mm length and 1 mm thick); the main and the interior cylinders are coaxial with the wire electrode. The distance between the interior cylinders and the exterior one is 20 mm [12].

II.2. EXPERIMENTAL SETUP

The experimental setup used in this work, comprises four distinct functional units: the admission of powder, the ESP, the air supply section and the measuring set. The schematic diagram of the experimental system is shown in "Fig.2 and the photo in Fig.3.

The experiments were performed in the laboratory of Applications of Plasma, Electrostatics & Electromagnetic Compatibility "APELEC" in the technology faculty of Sidi Bel Abbes, Algeria.

An autotransformer (1) (Metrel HSN 260V/4.5A) was used to vary the input voltage of the negative high voltage supply (2) (220V/40kV, 35mA) from 0 to 260VAC. This gives the possibility to change the value of high voltage of the corona wire in the ESP. an air blower (3) (DN-DF001) is installed at the input of the ESP to provide the air flow, connected itself to an autotransformer to adjust air velocity inside the ESP.

The current–voltage characteristics of the ESP were determined by using a digital multimeter (4) (connected to a high voltage probe for multimeter (5) (TESTEC HVP 40)).

The admission of polyvinyl chloride (PVC) particles, used as pollutant product, is provided by means of a vibratory feeder (6) which introduces it into the ESP, through a funnel placed at the inlet of the filter. A same sample of mass m=10g was used for each experiment, with a constant mass flow equals to 10g/30min. A box shape chamber (7) is connected to the output of the ESP which is used to recover the unfiltered powder in order to estimate the filtration of the ESP.

The experiments were carried out with an average gas flow velocity of 1.5 m/s (gas flow

velocity was determined using an anemometer) under 25°C temperature and 45% humidity.

Precipitation efficiency was determined by simultaneous direct measurements of the fly ash mass at the inlet to, and the fly ash mass in the chamber installed at the outlet of the ESP. Relevant computations were performed with the formula:

$$\eta(\%) = \left(\frac{m_{in}-m_{out}}{m_{out}}\right) \times 100\% \quad (1)$$

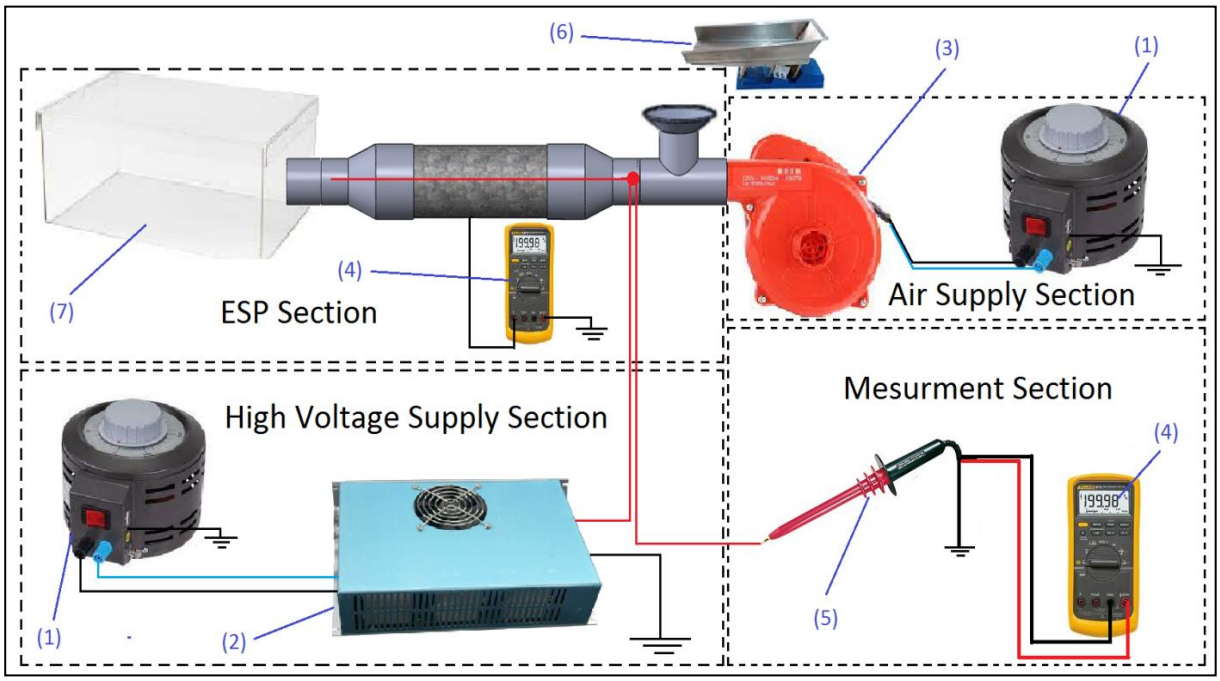

Fig. 2. Schematic of the experimental setup.

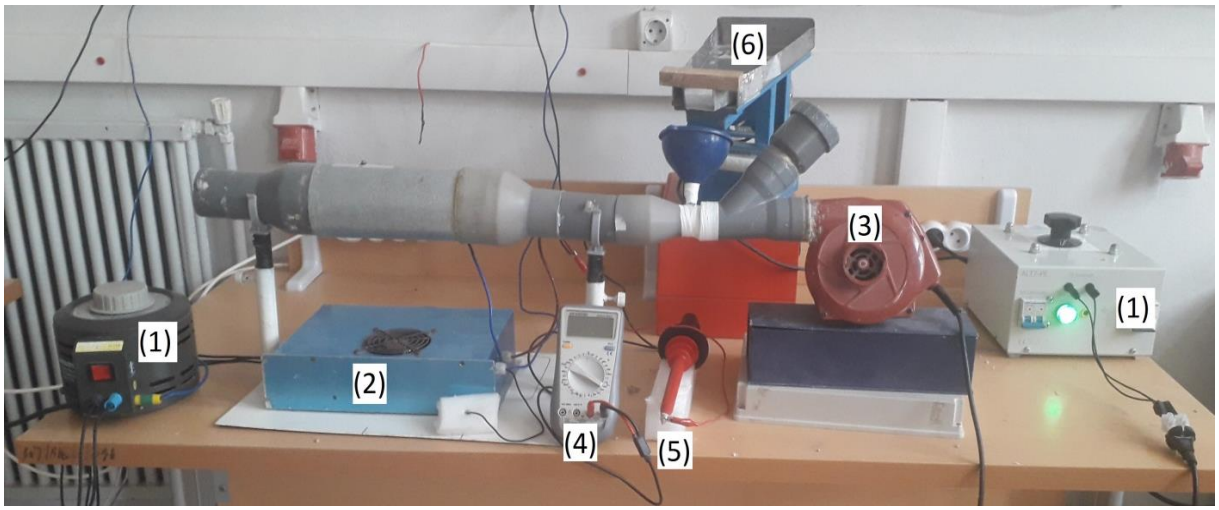

Fig. 3. Photography of the experimental setup.

III. RESULTS AND DISCUSSION

III.1. CURRENT–VOLTAGE CHARACTERISTICS

In order to evaluate more exactly the performance of Wire-Multicylinders electrostatic precipitators, the I-V characteristics of the precipitation were compared to another type of fly ash, incense smoke (coming from incense sticks combustion). Fig.4 illustrates the current as a function of the applied voltage of the ESP in

the case of PVC powder and incense smoke as a pollutant (separately).

It is clearly figured that the discharge current, in the case of the PVC powder, is much bigger than the case where the incense smoke is the pollutant. On another side, the breakdown voltage is higher in the case of PVC powder. This can be explained by the low resistivity of the incense particles (around 7.5×10^{10} Ω.cm [13]) comperes with PVC particles resistivity (10^{12} Ω.cm).

III.1. COLLECTION EFFICIENCY

Fig.5 illustrates the efficiency variations for PVC powder as a function of the applied voltage. The collection efficiency improves with the voltage. Thus, the higher efficiency that can be achieved is 84% of particle diameter of 180µm. With further increase in particle diameter (Fig.6), the collection efficiency improves due to the increase of particle surface which augments the number of charged species on it.

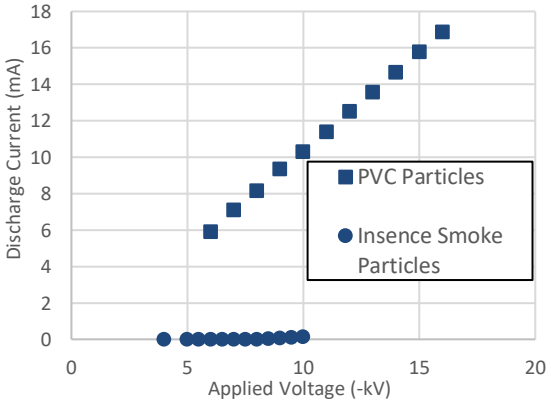

Fig. 4. Comparison between Current-voltage characteristics of the PVC powder and the incense smoke [1] (Temperature=25(°C); Humidity=45%).

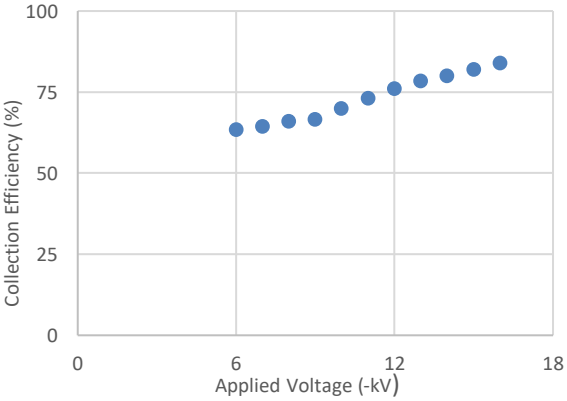

Fig. 5. Precipitation efficiency of the ESP as a function of the applied voltage (Particle Diameter = 180µm; Temperature = 25(°C); Humidity = 45%).

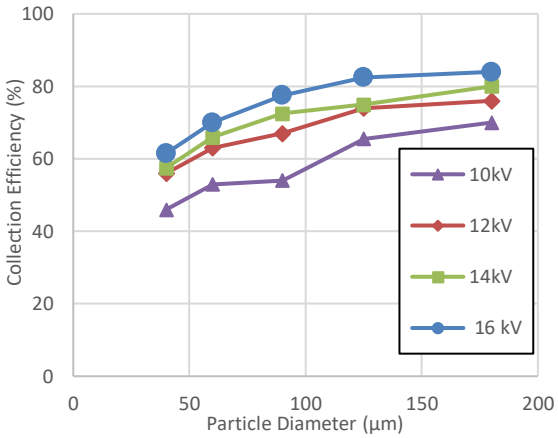

Fig. 1. Precipitation efficiency of the ESP as a function of the particle diameter for four (4) values of the applied voltage (negative DC) (Temperature=25°C; Humidity=45%).

IV. CONCLUSION

An experimental study was conducted in the present work to evaluate the new filtration arrangement of electrodes. Obtained results have shown that:

1) The comparative analysis of the corona discharge currents of the two types of particles used in this study shows that with the PVC particles the current is higher than with the incense smoke particles, owing to the large area of the PVC particles that enables the transfer of larger number of ions.
2) This new electrostatic precipitator is more effective with Submicron particles than micron particles for three assumed reasons: the first one is that this electrode geometry promotes the diffusion charging more than the field charging of particles; the second one is that the dimensions of the ESP are smaller so that the particles don't have enough space to be well charged. And the third one is that the high level of resistivity of the particles reduces the performance of the ESP.
3) The collection efficiency augments with the rise of the applied voltage and the diameter of particles. Because of the increase in the electric force with the voltage and in the particle surface.

Further analysis is required to apply it to other types of fly ash with different diameters and chemical proprieties.

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