Experimental study of corona discharge generated by a triode electrode system

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E-mail: lucian.dascalescu@univ-poitiers.fr ***Abstract*— The triode electrode system is frequently employed for accurately controlling the corona charging of insulating materials. It consists of a high-voltage corona electrode, a grounded plate electrode, and a grid electrode between them. The aim of the present paper is to analyze the characteristic features of a particular type of such an electrode system, and formulate a few recommendations on its design and use, in order to increase the efficiency of the charging process. The experiments were performed with a high-voltage wire-type dual electrode, located at a distance 20 to 45 mm above a grounded plate electrode (Aluminium; 165 mm x 115 mm). The distance between the metallic grid and the ground could be varied between 10 and 30 mm. The corona electrode consisted of a tungsten wire (diameter 0.2 mm) supported by a metallic cylinder (diameter 26 mm) and distanced at 34 mm from its axis. The wire and the cylinder were energized from the same adjustable high-voltage supply 100 kV, 3 mA. A well-defined potential was imposed between the grid and the grounded plate. In some experiments, a non-woven Polyester medium (sheet thickness: 400 μm, average fiber diameter: 20 μm) was placed on the surface of the grounded plate, to be charged by the corona discharge. The current-voltage characteristics of this type of electrode system were obtained for different values of the inter-electrode spacing and grid to ground distances, with and without the Polyester medium. Decreasing the distance between the electrode and the grid caused the increase of the corona current density, but the discharge zone was concentrated in a narrower zone at the surface of the collecting electrode.**

I. INTRODUCTION

Charging and discharging characteristics of non-woven fabrics have been most often investigated in relation with one particular class of applications: the electret filters for dust collection [1-3]. When used for the filtration of submicron particles from polluted gases, the fibers of the fabrics are electrostatically charged, in order to enhance the collection efficiency in comparison with that of mechanical filters. A good air-filter should be able to preserve a high level of electric charge for as long a time as possible.

A lot of work has already been done to characterize the various types of corona electrodes and to compute the electric field strength, as well as the ionic charge density they generate [4, 5]. Indeed, the efficiency of any such electrostatic process depends on the maximum magnitude but also on the spatial distribution of the electric field strength and of the ionic charge density in the corona discharge [4].

Various constructions have been described in the technical literature [4, 5], accompanied by current-voltage curves that enabled their comparison under certain well-defined conditions (distance to a grounded electrode, polarity of the high-voltage electrode). Corona discharge in wire-plate electrode arrangements has been thoroughly investigated, mostly in relation to the design of high-voltage DC or AC lines [5]. The experimental studies have clarified important practical issues, such as the onset voltage level of the corona discharge, the power losses, the influence of the ambient conditions (humidity, wind, ..). The researchers elaborated sophisticated numerical models for calculating the electric field and the space charge generated by a ionizing wire facing a plate electrode [5]. The triode electrode system is frequently employed for accurately controlling the corona charging of insulating materials [6, 7]. It consists of a high-voltage corona electrode, a grounded plate electrode, and a grid electrode between them.

The aim of the present paper is to analyze the characteristic features of a particular type of such an electrode system, and formulate a few recommendations on its design and use, in order to increase the efficiency of the charging process.

II. Experimental Study

The triode electrode system (Fig. 1) consists of a high-voltage wire-type dual electrode, facing a grounded plate electrode (aluminium; 250 mm x 130 mm), and a grid electrode.

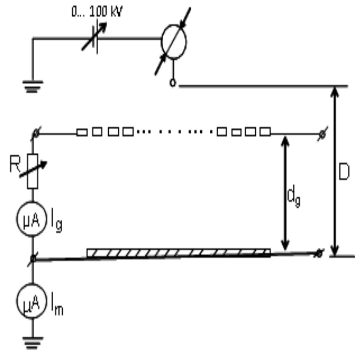

Fig. 1. Triode electrode system employed for the corona-charging of non-woven fabrics

The high-voltage electrode consists in a tungsten wire (diameter 0.2 mm) supported by a metallic cylinder (diameter 26 mm) and distanced at 34 mm from its axis. The wire and the cylinder were energized from the same adjustable high-voltage supply 100 kV, 3 mA (model SL 300 Spellman, Hauppauge, NY), as shown in Fig. 1. Unless otherwise specified, the distance between the wire and the surface of the plate electrode was D = 20 to 45 mm.

The grid (fig. 2) is connected to the ground through a series of callibrated resistors having a total resistance R. In this way, for an intensity I, a well-defined potential V_g = RI is imposed between the grid and the grounded plate on which the samples are positioned. Part of the charge carriers generated by the corona electrode pass through the grid and are driven by this potential to the surface of the non-woven medium, which retains them.

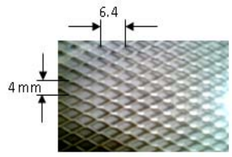

Fig. 2. Aspect of the grid electrode (grid wire diameter: 1.18 mm).

III. EXPERIMENTAL PROCEDURE

In a first set of experiments, a non-woven Polyester medium (sheet thickness: 400 μm, average fiber diameter: 20 μm) was placed on the surface of the grounded plate, to be charged by the corona discharge. The current-voltage characteristics of this type of electrode system were obtained for different values of the inter-electrode spacing D and of the grid to plate distance dg, with and without the Polyester medium, at constant ambient conditions: 23.7°C; RH = 49.9%. The current was measured with an analog micro-ammeter. The high-voltage was read on the front-panel of the power supply.

A second group of experiments was carried out by changing the grid-to-plate distance dg, at fixed D = 40 mm. In a third set of experiments the study of the distribution of current density at the surface of the collecting electrode proved to be an effective method for the evaluation corona-charging efficiency of this electrode system. The experimental set up is shown in figure 3.

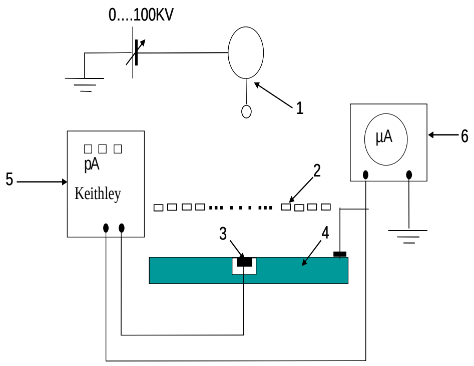

Fig. 3. Experimental setup for the distribution of corona current at the surface of the grounded electrode.

IV. Results and Discussion

A. Current-Voltage Characteristics

1) Influence of non-woven Polyester medium presence

The current-voltage characteristics obtained for this experiment can be examined in figure 4. The presence of the medium MC362 Polyster on the surface of the electrode plate has significantly changed the current-voltage characteristics. At a given voltage and for the same spacing between electrodes D and d_g, the corona current is higher for an electrode without non-woven MC362 Polyester medium, and the corona onset voltage is lower.

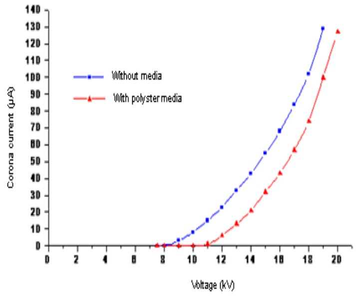

Fig. 4. Current-voltage characteristics of triode electrode system for D = 20 mm and d_g = 10 mm at V_g = 2 kV.

2) Influence of grid spacing

The experimental results presented in figure 5, show that the corona onset (V_{onset}) and the corona current depends on the distance between electrode and grid dg. For the same distance between electrodes D, the larger the distance dg, the lower is the corona onset voltage V_{onset} . At a given voltage and for the same spacing between electrodes D, the corona current is larger at smaller inter-electrode spacing dg. Indeed, the discharge current increases rapidly by decreasing t he distance between electrodes.

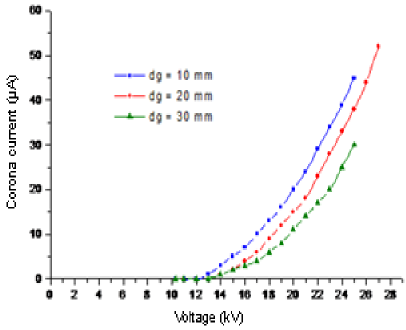

Fig. 5. Current-voltage characteristics of triode electrode system for D = 40 mm at V_g = 2 kV

B. Corona Current Density Distribution

The study of corona current density distribution in the plane of the grounded electrode is an effective method for evaluating the charge density created by an ionizing electrode. Measurements were made using the ionizing electrode wire, varying the inter-electrode spacing D and the distance between the grid and the plate dg. The corona current density distribution on the surface of grounded electrode in figure 6 indicates that the corona is larger for an electrode with d_g = 20 mm than at d_g = 10 mm. So the increased grid-to-plate distance d_g causes a wider corona discharge.

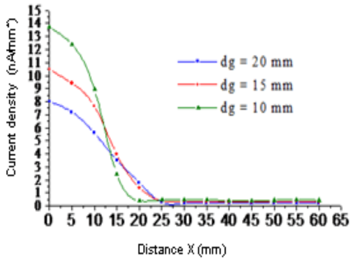

Fig. 6. Current density distribution obtained for D = 30 mm at V_g = 4 kV

V. CONCLUSION

(1) The presence of the Polyester medium drastically alters the current-voltage characteristics of the electrode system.
(2) When the distance between the electrodes and the grid decreases, the corona current increases, but it concentrates on a narrower zone at the surface of the ground electrode.

REFERENCES

[1] F J. Rornay, B. Y H. Liu, and S.-J. Chae., “Experimental Study of Electrostatic Capture Mechanisms in Commercial Electret Filters,” Aerosol Science and Technology, vol. 28,1998.

[2] D.C. Walsh and J. I. T. Stenhouse., “Parameters Affecting the Loading Be havior and Degradation of Electrically Active Filter Materials,” A.Science and Technology, vol. 29, pp. 419-432, 1998.

[3] M. Nifuku, Y. Zhou, A. Kisiel, T. Kobayashi, and H. Katoh, “Charging characteristics for electret filter materials,” J. Electrostat., vol. 51-52, pp. 200-205, 2001.

[4] A. Bendaoud, L.Dascalescu, M.Blajan, A.Samuila, A.Stochita, P.V. Notingher, Corona charging of granular layers of insulating particles at the surface of a grounded electrode, J. Electrostat., 63 (2005) 643-647.

[5] A. Bendaoud, A.Tilmatine, K. Medles, O. Blejan, L. Dascalescu, Experimental study of corona discharge generated in a modified wire-plate electrode configuration for electrostatic processes applications, IEEE Trans. Ind. Appl., 46 (2010) 666-671.

[6] L.M. Dumitran, O. Blejan, P. Notingher, A. Samuila, and L. Dascalescu, “Particle charging in combined corona-electrostatic fields,” IEEE Trans. Ind. Appl., vol. 44, no. 5, September/October 2008, pp. 1385-1390.

[7] Oda T and Ochiai , Charging characteristics of a nonwoven sheet air filter, J 1988 Proc. 6th Int. Symp. on Electrets, pp. 515 – 519

[8] Tabti, B; Mekideche, MR; Plopeanu, MC; Dumitran, LTM; Herous, L; Dascalescu, L, Corona-Charging and Charge-Decay Characteristics of Nonwoven Filter Media, 2010, IEEE Trans. Ind. Appl. 46 634

[9] A. Bendaoud, A. Tilmatine, K. Medles, M. Rahli, M. Huzau, L. Dascalescu, “Caracterisation of dual corona electrodes for electrostatic processes applications,” IEEE Trans. Ind. Appl., vol. 44, no. 3, May/June 2008, pp. 692-698.

[10] K. Adamiak, “Particle charging by unipolar ionic bombardment in an AC electric field,” IEEE Trans. Ind. Appl., vol. 33, vol. 2, March/April 1997, pp. 421–426.

[11] L. Dascalescu, A. Mizuno, R. Tobazéon, A. Iuga, R. Morar, M. Mihailescu, A. Samuila, “Charges and forces on conductive particles in roll-type corona-electrostatic separators,” IEEE Trans. Ind. Appl., vol. 31, 1995, pp. 947–956.