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Impact of Wire Spacing on Surface Potential Uniformity in PP Films Corona Charged by Two - and Three-Wire Electrodes

Allaoua Rahmani¹, Ouarda Chibane¹, Karima Smili^{2,3}, Karim Medles⁴,

Thami Zeghloul⁴, Lucien Dascalescu⁴

Abstract— Corona discharge is applied in a wide range of industries, including ozone generation, surface treatment, and specifically in electrostatic applications including electrostatic precipitation and separation. Corona discharge is an efficient method of charging insulating films, non-woven media, and granular materials in certain situations. The success of the process depends on the degree and consistency of the electric charge distribution on the surfaces of the materials being exposed. The goal of this work is to assess the uniformity of discharge generated by two-wire or three-wire corona electrodes by modifying the distance between wires. The experiments were carried out with the objective to record the electric potential at the surface of polypropylene (PP) films after exposure to a corona discharge generated by these electrode configurations. The obtained results revealed that the uniformity of the charge distribution depends on the number of wires and the relative distance between them.

Index Terms— Corona discharge, charging uniformity, current density, surface potential distribution, polypropylene films.

I. INTRODUCTION

The wide range of applications for electrostatic separation has propelled a rapid development of various equipment designed to adapt to the specific requirements of each use case [1]-[4]. Corona discharge electrode system is one of those equipment. A wide variety of corona electrodes have been developed in order to improve the uniformity and the level of the charging [5]-[8]. Wire-type corona electrode are the most widely used because of their simplicity and low cost [9].

The wire-type electrode generate corona discharges quite uniformly distributed along the emitting element. In order to study the uniformity in the transversal direction, the potential profile at PP films surface was measured by a non-contact electrostatic probe. The non-contact measurement of the surface potential remains a practical tool for studying the distribution of charges on insulating surfaces.

This paper aims to evaluate the uniformity of discharge generated by two- or three-wire corona electrodes by modifying the distance between wires. The obtained results concluded that selecting the optimal number of wires and the suitable spacing between them can significantly improve the uniformity of corona charging.

II. EXPERIMENTAL PROCEDURE

The experiments were performed on (210 mm × 50 mm) and (297 mm × 50 mm) samples cut from the same polypropylene films, in ambient air (temperature: 19 °C – 21 °C; relative humidity: 55% – 68%).

The samples were placed on an aluminium plate connected to the ground. The electric charging of the samples was performed using two models of corona electrodes, comprising two or three copper wires of diameter 0.25 mm, spaced at a variable distance d from 20 mm to 80 mm in 20 mm steps. The wires were stretched by insulating supports and located at a distance $h = 30$ mm from sample. They were supplied by a high DC voltage power supply (model ISEG T1CP 300 304 P, 30 kV, 0.3 mA). The sample maintained immobile and centred under the active electrode was exposed to a continuous corona discharge for 1 s.

After charging had been completed, the sample was transferred, using a carrier placed on a belt conveyor, under an electrostatic probe (model 3450, Trek, Inc., Medina, NY), connected to an electrostatic Voltmeter (Model 341B, Trek), to measure the surface electric potential along its axis (xx') in transversal direction to the electrode (Fig. 1).

III. RESULTS AND DISCUSSION

A. Current-Voltage characteristic

The I-V characteristics were measured for various values of the inter-wire spacing d in three-wire-plane electrode configurations as it is highlighted in Fig. 2 shown below. The results indicate that, for a fixed voltage, the corona discharge current increases with an increase in the distance d between wires. This phenomenon can be attributed to the reduction in the mutual shielding effect exerted by the wires on each other. This effect amplifies as the spacing between wires decreases, thereby

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reducing the discharge current for each wire, and consequently, lowering the total current at the plate.

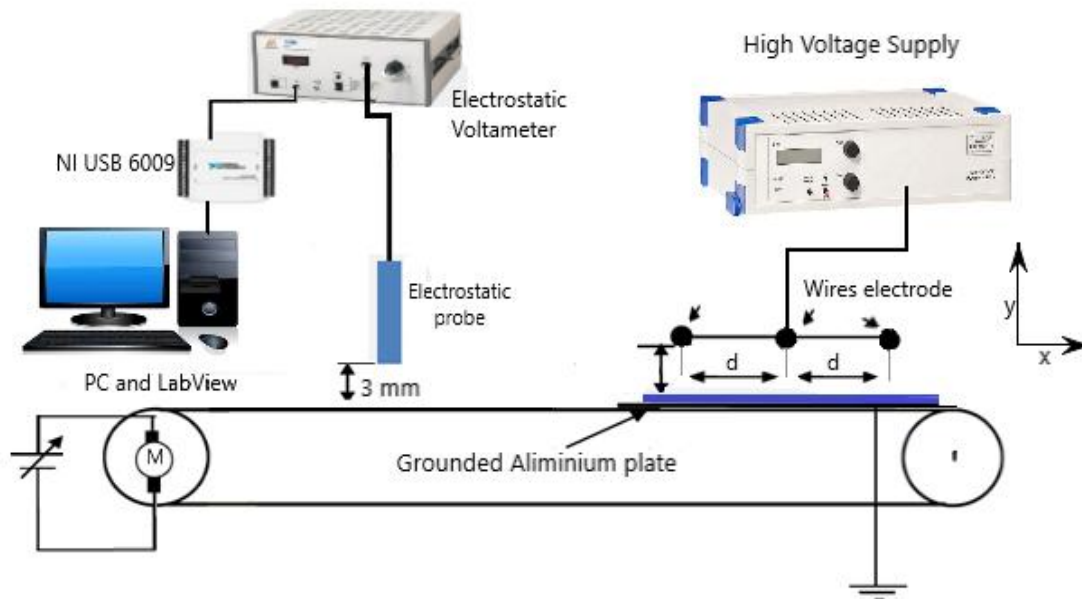


Fig. 1. Experimental setup for the measurement of electric potential profile at the surface of polypropylene (PP).

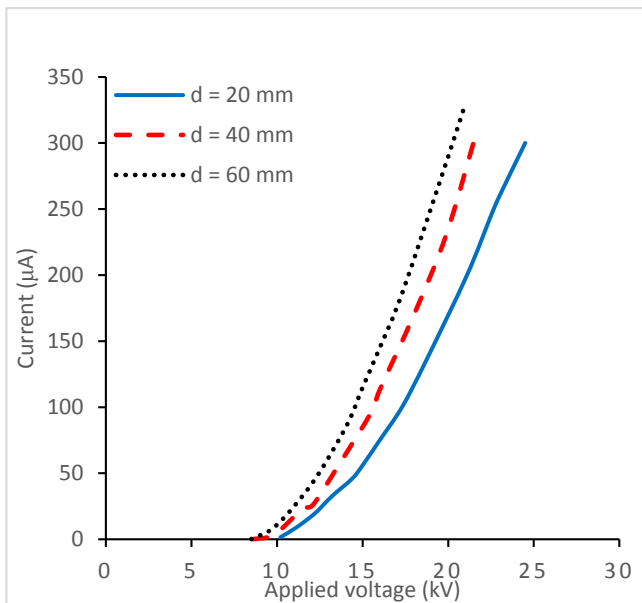


Fig. 2. Current-Voltage characteristics in three-wire-plane arrangement for different values of wire-to-wire spacing d ; ($h = 30$ mm)

B. Current Density Distribution

Fig. 3 pointed out below depicts the distribution of current density on the plane surface in the three-wire - plane electrode system for varying inter-wire distances d . The applied high voltage was maintained at $U = 15$ kV as it can be seen in Fig. 3 shown below.

The current density profile had a distribution with maximum and minimum values located respectively under each wire and

midway between two neighbouring wires. Furthermore, the current density peak values obtained for a spacing of 40 mm were lower than those obtained for a spacing of 80 mm. This is due to the shielding effect exerted between the wires. The peak value of the central wire is lower than that of the end wires due to the influence of a single nearby wire on the ends, while the central wire is influenced by two neighbouring wires.

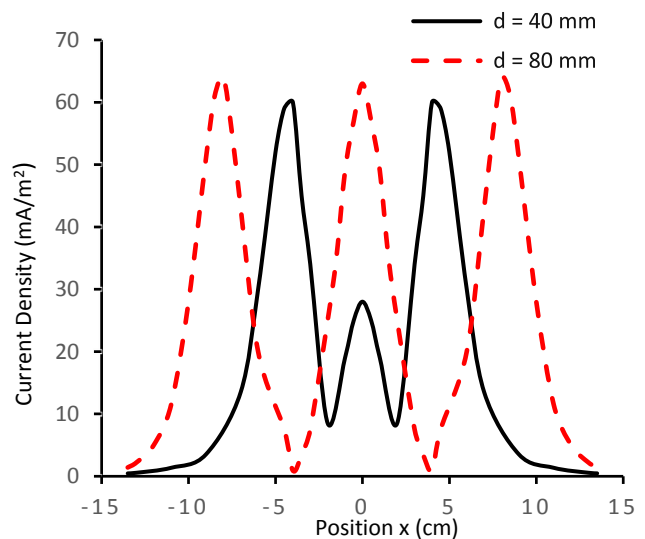


Fig. 3. Current density distribution in three wire-plane configurations for different values of wire-to-wire spacing d ; ($U = 12$ kV, $h = 30$ mm)

C. Electric potential distribution

Fig. 4 and 5 illustrate the impact of the change in wire-to-wire spacing d on the surface electric potential. Samples are charged with two-wire and three-wire electrodes for the same high voltage $U = 15$ kV and transferred with the same speed $v = 8.2$ cm/s.

The influence of the interaction between adjacent wires is readily apparent, and it becomes more clearer as the distance d decreases. This interaction leads to a drop in the charge level, specifically for the two-wire-plane electrode at an inter-wire spacing of $d = 20$ mm. In this case, the loading level decreases by 18%, as shown in Fig.4. In Fig.5, it is observed that the peak value of the center wire in the three-wire-plane electrode is attenuated at an inter-wire spacing of $d = 40$ mm. Additionally, it is important to mention that increasing the spacing between the inter wires, denoted as d , results in the expansion of the charged surface.

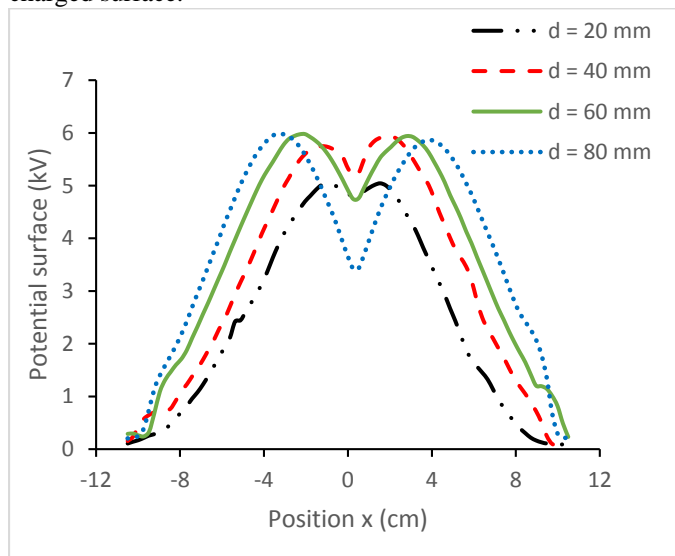


Fig. 4. Effect of wire-to-wire spacing d on the repartition of the surface electric potential along the x -axis at the surface of polypropylene charged in two-wire-plane configuration; ($h = 30$ mm; $U = 15$ kV; $t = 1$ s).

D. Charging uniformity

The electrodes of the two-and three-wire kind produce corona discharges that are uniformly distributed along the emitting elements. The rate of uniformity in the transversal direction of the deposited charge on PP films surface is evaluated considering various distances between wires. According to Fig. 4 and 5, the electric charge is not uniformly distributed in the transversal direction. A high potential level was recorded in the areas just under the wires indicating a high level of charge. A low potential level was recorded in the areas located between the wires indicating that the charge density is lower. The uniformity ratio coefficient was introduced and calculated using the following formula, as in (1) [10]:

$$\left[\left(1 - \frac{\Delta V}{V_{max}} \right) \right] \times 100\% \quad (1)$$

Where ΔV is the difference between values of the maximum and minimum surface potential measured in the zones of width d for the two-wire electrode and $2d$ for the three-wire electrode located between and under the end wires, V_{max} is the maximum value of the unregistered surface potential in this zone. The results obtained are presented on the Fig.6 and 7

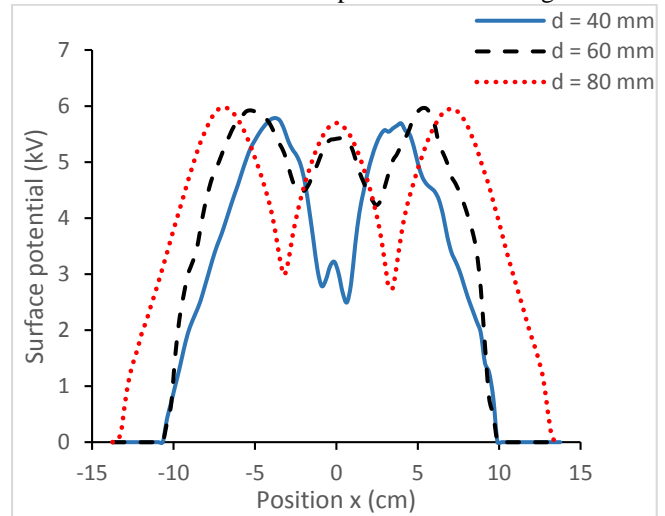


Fig. 5. Effect of wire-to-wire spacing d on the repartition of the surface electric potential along the x -axis at the surface of polypropylene charged in three-wire-plane configuration ($h = 30$ mm; $U = 15$ kV; $t = 1$ s).

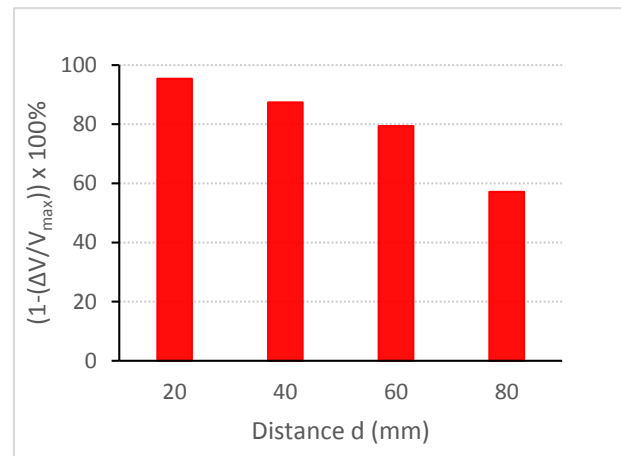


Fig. 6. Effect of the distance between wires on uniformity ratios for corona charging of PP films by two-wire electrode ($h = 30$ mm; $U = 15$ kV; $t = 1$ s)

For the two-wire - plane electrode system, the degree of uniformity increases gradually as the distance between wires decreases. For the distance $d = 20$ mm, the rate of uniformity exceeded 95% but the shielding effect reduced the level charging of the films Fig. 6.

For the three-wire-plane electrode system, the best uniformity was obtained for the distance $d = 60$ mm (70%). At shorter distance between wires, the uniformity was deteriorated because in this configuration, the centre wire is influenced by two neighbouring wires indeed the Shielding effect is more

important and the surface under this wire is low charged as shown in Fig.7

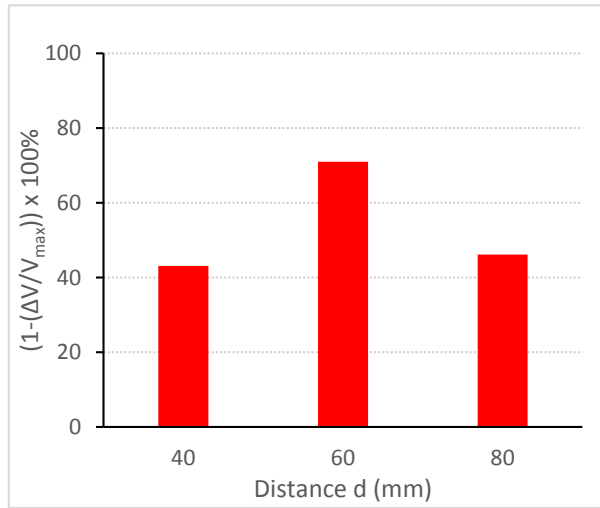


Fig. 7. Effect of the distance between wires on uniformity ratios for corona charging of PP films by three-wire electrodes ($h = 30$ mm; $U = 15$ kV; $t = 1$ s).

IV. CONCLUSION

In this paper, the effect of the distance between wires on of the corona discharge generated by two-wire and three-wire electrode configurations and the uniformity of the charge deposited on the PP film surface has been investigated. The obtained results indicate that the current density and surface electric potential profiles exhibit a peak beneath each wire and a trough at the midpoint between two adjacent wires. Furthermore, it was concluded that the number of wires and the wire-to-wire spacing affect the distribution of the corona current density and the surface electric potential on corona-charged PP films. It is worth noticing that the distance between wires should be large enough to avoid the shielding effect which diminish the level of the corona charging. The uniformity of the electric charge deposited on the surface of PP film samples exposed to corona discharge is significantly influenced by the distance between wires. For the two-wire electrode, the best uniformity is achieved with a shorter distance d . In the case of three-wire electrode, the optimal circumstances for optimizing the uniformity and amount of corona charging, it is crucial to select the appropriate spacing between wires for each electrode arrangement.

REFERENCES

- [1] K. Medles, K. Senouci, A. Tilmatine, A. Bendaoud, A. Mihalcioiu, L. Dascalescu, "Capability Evaluation and Statistical Control of Electrostatic Separation Processes", IEEE Trans. Ind. Appl, Vol. 45, no. 3, pp. 1086-1094, May-June 2009.
<https://doi.org/10.1109/TIA.2009.2018903>
- [2] F. S. Knoll and J. B. Taylor, "Advances in Electrostatic Separation, Minerals and Metallurgical Processing", pp.106-114, Vol. 2, no. 2, May 1985
<https://doi.org/10.1007/BF03402605>
- [3] Y. Higashiyama and K. Asano, "Recent Progress in Electrostatic Separation Technology, Particulate Science and Technology", Vol. 16, no. 1, pp.77-90, 1998
<https://doi.org/10.1080/02726359808906786>
- [4] A. Iuga, I. Cuglesan, A. Samuila, M. Blajan, D. Vadan, and L. Dascalescu, "Electrostatic Separation of Muscovite Mica from Feldspathic Pegmatites", IEEE Transactions on Industry Applications, Vol. 40, no.2, pp.422-429, 2004.
<https://doi.org/10.1109/TIA.2004.824506>
- [5] L. Dascalescu, A. Iuga, R.Morar and A. Ifrim, "corona discharge electrodes for improved electrostatic separation of electroinsulating materials", Annual report of conference electrical insulation and dielectric phenomena, pp. 143-148, 1989.
- [6] C. Beelee, A. S. Wexler, N. C. Tien, D. A. Niemeier, and B. A. Holmen, "Electrical Mobility Separation of Airborne Particles Using Integrated Microfabricated Corona Ionizer and Separator Electrodes, Journal of Microelectromechanical Systems", Vol. 18, no. 1, pp. 4-13, 2009.
<https://doi.org/10.1109/JMEMS.2008.2011123>
- [7] A. Reguig, A. Bendaoud, A. Bouteffaha, H. Boudra, A. Tilmatine and L. Dascalescu, "ground-shielded dual-type high-voltage electrode for corona charging applications", IEEE Transactions on Industry Applications, Vol. 53, no. 2, pp. 1439 - 1445, March-April 2017.
<https://doi.org/10.1109/TIA.2016.2628904>
- [8] O. Chibane, A. Rahmani, K. Smili, B. Bendahmane, L. Dascalescu and K. Ahmed, " Experimental characterization of multi-wire corona electrode configurations" J. Electrostat, vol. 111, pp 1-8, 2021.
<https://doi.org/10.1016/j.elstat.2021.103575>
- [9] A.Iuga, A.Samuila, M.Blajan, R.Belega, R. Morar, and L. Dascalescu, "Characterization of wire corona electrodes at various discharge gaps in electrostatic separation processes", Conference Record of the 2004 IEEE Industry Applications Conference, 39th IAS Annual Meeting 2004.
- [10] M. S. Bendilmi, T. Zeghloul, Z. Ziari, K. Medles, L. Dascalescu "Experimental Characterization of a Tri-Needle-Type Corona Electrode in View of Improving Charging Uniformity", IEEE Transactions on Industry Applications, Vol. 58, Issue 1, 783-791, Jan.-Feb. 2022.
<https://doi.org/10.1109/TIA.2021.3130012>