ANALYSIS OF ELECTRIC FIELD DEPENDING ON THE DIAMETER OF THE BALL ELECTRODE

Ondřej BAŤKA, Jaroslav BERAN, Josef SKŘIVÁNEK

Department of textile machine design - Technical University of Liberec, Liberec, Czech Republic, EU,
ondrej.batka@tul.cz

Abstract

This paper deals with the analysis of the distribution of the electric field around the spinning electrodes used for the production of nanofibres by the AC-electrospinning method. Understanding the behavior of the electrostatic field around the electrodes is an important part for design a spinning device. The performed analyzes were carried out depending on the previously performed optimization of the shape of the spherical electrode, which ensures a uniform distribution of the intensity of the electric field across the functional surface of the electrode. Analyzes were performed for multiple diameters of the spherical electrode and the dependence of the intensity of the electric field on the electrode diameter was monitored. Furthermore, the electrical voltage dependence on the electrode diameter and surface was monitored at the same electric field strength.

Keywords: Electric field, spinning electrode, spinning process, electrospinning

1. INTRODUCTION

This article builds on the research that was described in the paper "Analysis and optimization of the ball-shaped electrodes designed for AC-electrospinning" published at Nanocon 2016 [1]. The article describes the optimization of the shape of a spherical electrode designed for the production of nanofibers by the method AC-electrospinning, which was developed at the Technical University of Liberec [2]. The optimization was performed to achieve a uniform distribution of the electric field on the ball surface of the electrode. [1] **Figure 1** shows the result of the electric field simulation for an optimized electrode, taken from [1]. This shape was used as the default for further simulations. Simulations were performed for electrodes of different diameters and the electric field dependence on the size of the spherical head of the electrode was monitored. As described above, for the stability of the electrospinning process, it is important that the intensity be evenly distributed throughout the ball head, so that the electrode shapes for all the analyzed diameters are optimized.

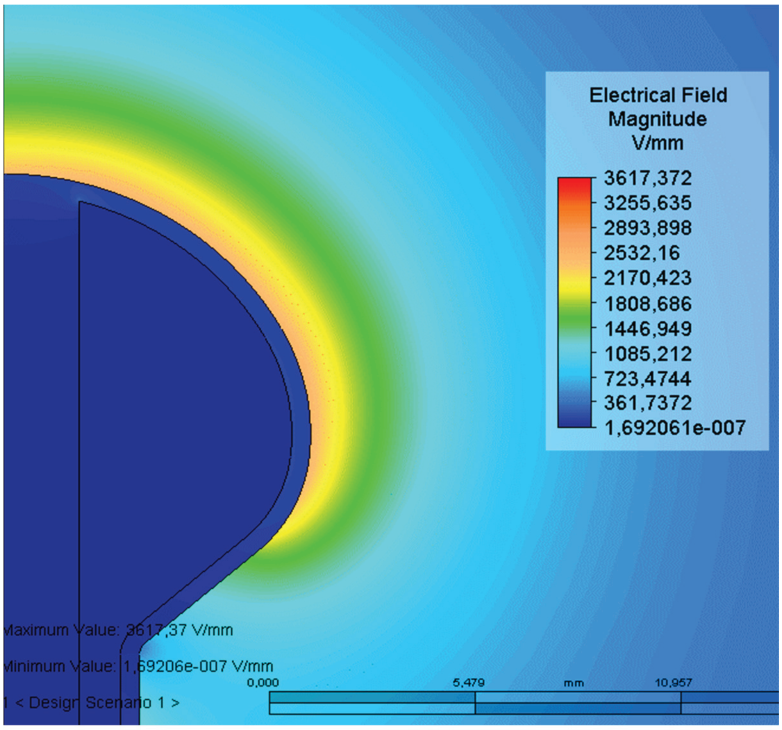

Figure 1 optimized electrode [1]

2. SIMULATION

Figure 2 shows a cross section of the electrode. The electrode is formed by a tube which is provided with a spherical spinning head at its upper end. As can be seen from the **Figure 2**, the head is not an accurate sphere, but it is made up of four radiuses. (R1, R2, R3, R4) Changing the magnitude of these radii was done by optimizing the shape so that the electric field was evenly distributed throughout the electrode head. Simulations were made for four different outer diameters of the electrode head (ϕD), specifically for diameters 11, 13, 15 and 17 mm. For all simulations performed, the same regional conditions were selected. An electrical voltage of 25 kV was applied to the electrode. In the distant surroundings of the spherical shape a voltage of 0 V was entered. Steel was chosen as the material of the electrode. Next, a thin layer of PVB polymer was imitated on the electrode surface. Surrounding of the electrode is air. **Figures 3** and **4** show the results of simulated for all optimized electrode shapes. The results show that the electric is evenly distributed in the ball head. The intensity at the point of transition of the spherical part to the pipe rapidly decreases. This part of the electrode is not functional for the spinning because the intensity values in this part are so small that there is no fiber production. Only the head of the electrode is therefore important

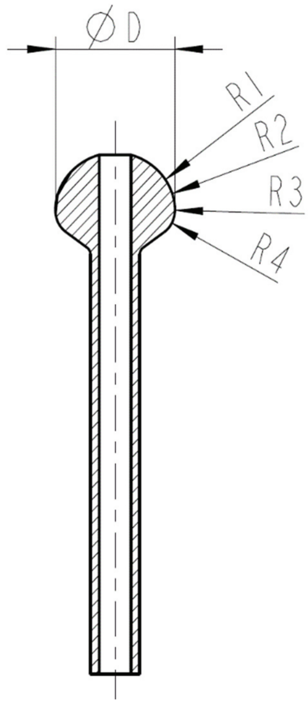

Figure 2 shape of electrode

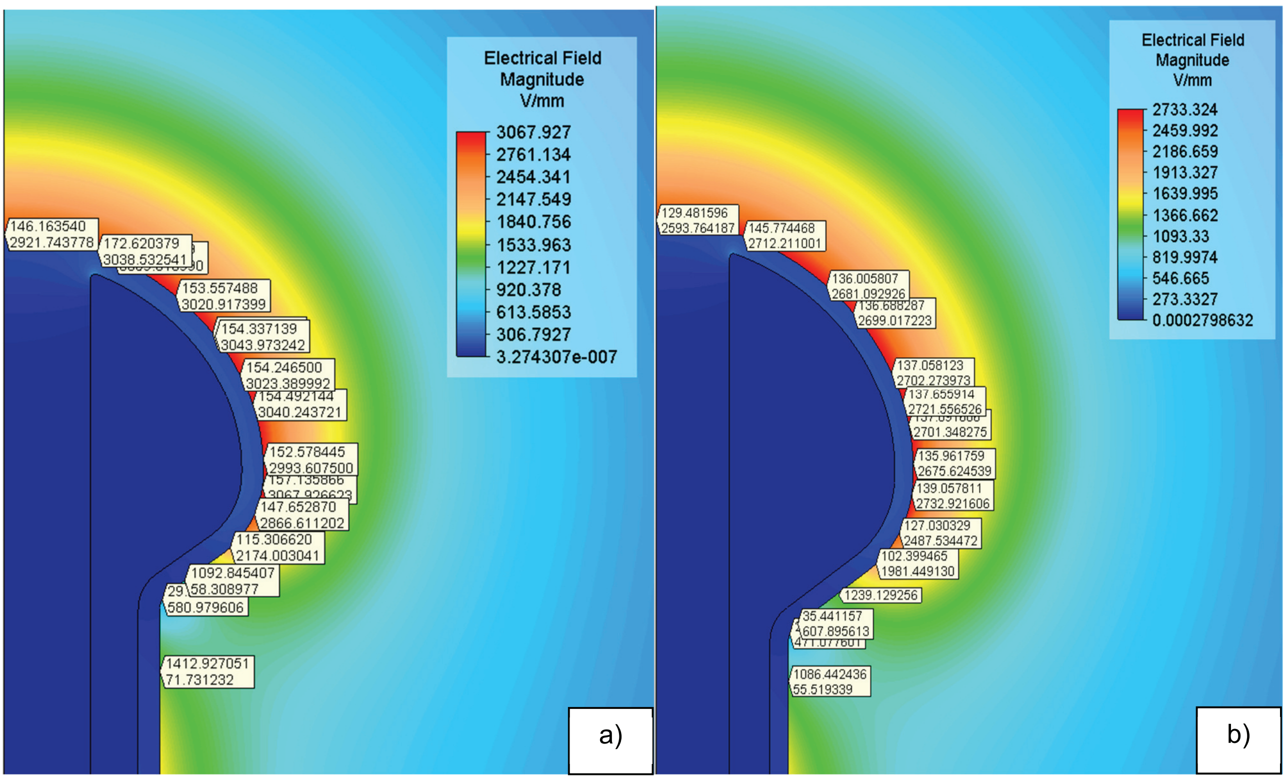

Figure 3 Simulation results, a) diameter 11 mm, b) diameter 13 mm

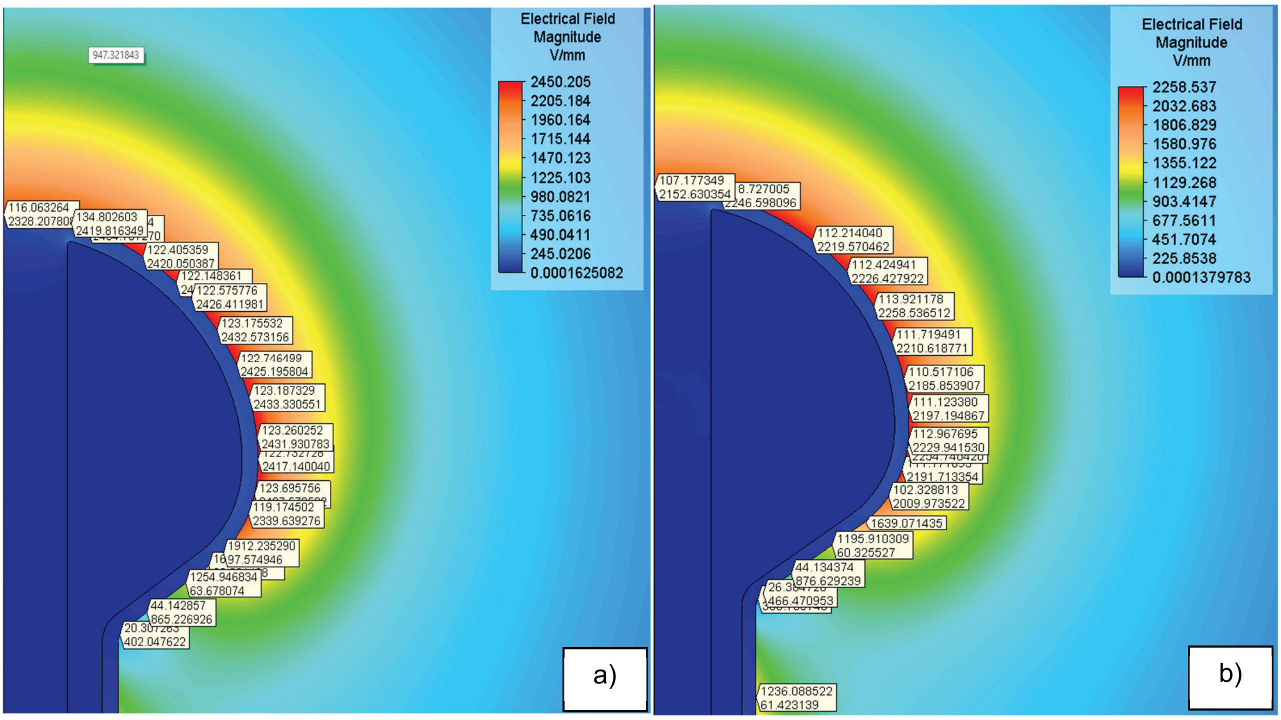

Figure 4 Simulation results, a) diameter 15 mm, b) diameter 17 mm

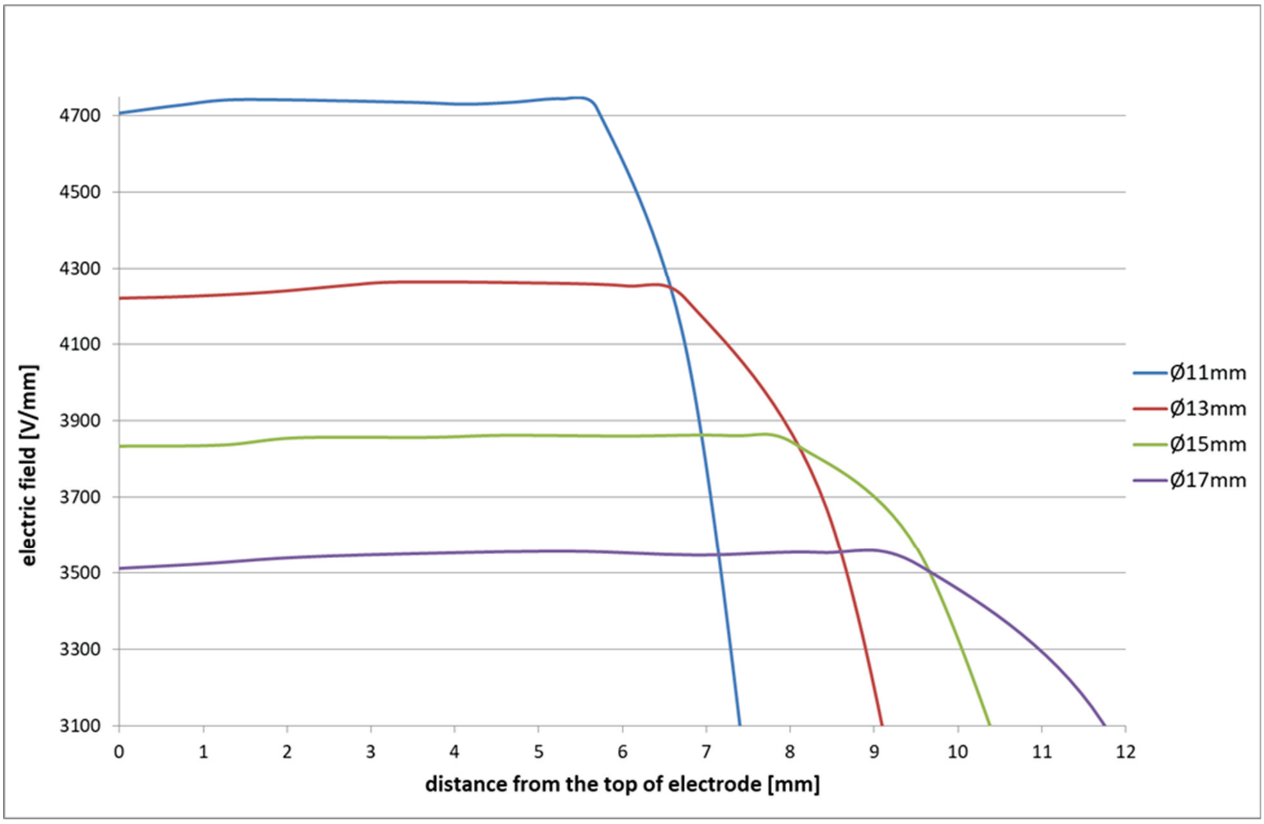

Figure 5 distribution of electric field

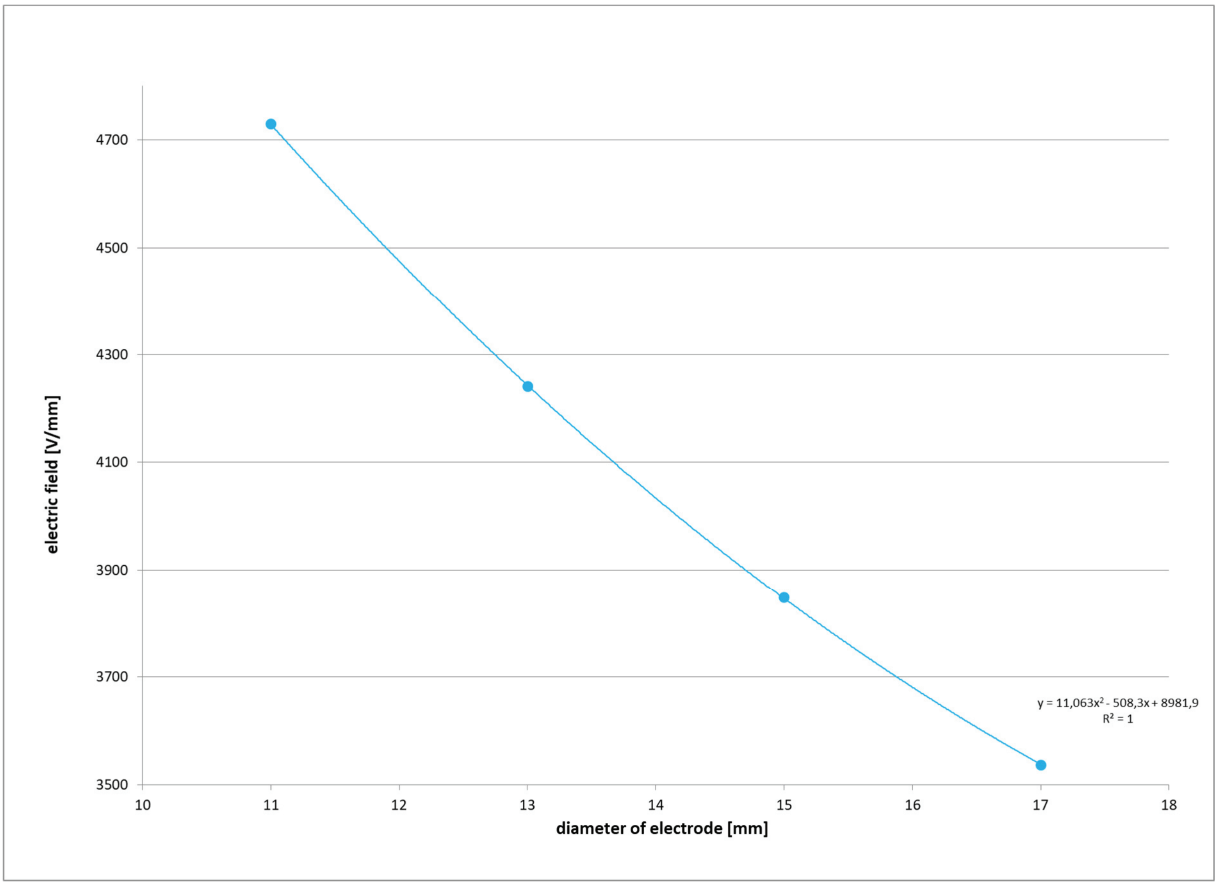

Figure 6 Electric field dependence on diameter of electrode

3. CONCLUSION

It follows from these simulations that the optimization of the shape of the electrode for the purpose of uniformity of the electric field can be done for more diameters of the electrodes. Further, it is observable from the graphs of **Figures 5** and **6** that with the increasing diameter the values of the electric field intensity on the surface of the electrode decrease. The values in the graph in **Figure 6** are obtained as the average of the electrode head values in the range where the electric field values are uniform. The electric field value is important for the stability and efficiency of the electrospinning process and also affects the resulting fibers. With an increasing electric field, the efficiency of the electrospinning process increases. Simulation results show that it is better to use smaller diameters of the electrodes for higher production efficiency. However, the surface area of the electrode also influence the efficiency of the process because more fibers are produced on the larger surface. Therefore, it would be advisable to devote this task in the future to laboratory measurements.

ACKNOWLEDGEMENTS

The research presented in this article was supported by the Ministry of Education, Youth and Sports in the framework of the targeted support of the "National Programme for Sustainability I" LO 1201

This publication was written at the Technical University of Liberec as part of the project " Research and development of devices for production of nanofibrous materials using AC-electrospnning process " with the support of the Specific University Research Grant, as provided by the Ministry of Education, Youth and Sports of the Czech Republic in the year 2016.

REFERENCES

[1] BATKA O., BERAN J., STRNAD M., SKRIVANEK J., Analysis and optimization of the ball shaped electrode designed for the AC-electrospinning, (2016) *NANOCON 2016 - Conference Proceedings, 8th International Conference on Nanomaterials - Research and Application*, pp. 358-361. ISBN: 978-808729471-0.

[2] LUKAS, D., et al.: Process for preparing polymeric nanofibers by spinning a solution of polymer melt in electric field and linear form of polymeric nanofibers prepared in such a manne *CZ 304173*.

[3] BAŤKA O., LE VAN, K., BÍLEK, M., SKŘIVÁNEK, J., VALTERA, J., Analysis of electric field around wire spinneret (2017) *NANOCON 2017* - Conference Proceedings, 9th International Conference on Nanomaterials - Research and ApplicationVolume 2017-October, 2018, pp 241-245. ISBN 978-80-87294-81-9.

JIRSAK, O., et al.: A method of nanofibers production from polymeric solution using electrostatic spinning and device for carrying out the method. Technical University of Liberec. WO2005024101 (A1). 2015.

[4] OLDRICH JIRSAK, PETR SYSEL, FILIP SANETRNIK, JAKUB HRUZA, and JIRI CHALOUPEK, “Polyamic Acid Nanofibers Produced by Needleless Electrospinning,” Journal of Nanomaterials, vol. 2010, Article ID 842831, 6 pages, 2010. doi:10.1155/2010/84283

[5] XIN WANG, HAITAO NIU, XUNGAI WANG, and TONG LIN, “Needleless Electrospinning of Uniform Nanofibers Using Spiral Coil Spinnerets,” Journal of Nanomaterials, vol. 2012, Article ID 785920, 9 pages, 2012. doi:10.1155/2012/785920.

[6] SKRIVANEK J., BATKA O., BILEK M., VALTERA J., LE VAN K., Effect analysis of the string cross-section on the electrostatic spinning proces. (2017) NANOCON 2017 - Conference Proceedings, 9th International Conference on Nanomaterials - Research and ApplicationVolume 2017-October, 2018, pp 224-228.

[7] YOUN-MOOK L., HUI-JEONG G, JOON PYO J, YOUNG-CHANG N. Preparation of Cellulose-based Nanofibers Using Electrospinning [online] URL: <http://www.intechopen.com/books/nanofibers/preparation-of-cellulose-based-nanofibers-using-electrospinning>