ANALYSIS OF ELECTRIC FIELD AROUD WIRE SPINNERET

BAŤKA Ondřej, LE VAN Khoa, BÍLEK Martin, SKŘIVÁNEK Josef, VALTERA Jan

Department of textile machine design - Technical University of Liberec, Liberec, Czech Republic, EU,
ondrej.batka@tul.cz, khoa.le.van@tul.cz, martin.bilek@tul.cz, Josef.skrivanek@tul.cz, jan.valtera@tul.cz

Abstract

The paper deals with the analysis of the equipment for electrospinning from the free layer using wire spinneret. Simulations of the electrostatic field were performed by using the finite element method. Main part of simulations is focused on analyzing the influence of shape of wire on the distribution of electric field around the wire. The influence of design dimensions of spinning machine was observed as well. Next part of simulations deals with influence of the electric voltages among wire, collector and background. According to the simulations the experiments were done. Main part of the experiments was focused on measurement of critical electric voltages. The conclusion compares simulations to results of experiments.

Keywords: Electric field, spinneret, wire

1. INTRODUCTION

This paper deals with simulations of the electrostatic field around the wire electrodes using several choice of construction parameters. The effect of the geometry and cross-section of the string on the intensity of its surface was monitored. Electrical intensity has a significant effect on electrospinning [1], [2]. Its size can affect the productivity of the process of production of nanofibers. Another point was the determination of the critical intensity, which is the intensity at which the first nanofibers begin to form. These values were simulated based on the values of the critical voltages obtained during the experiments. These voltages were experimentally obtained for every each type analyzed electrode. The influence of voltage between the electrode and the collector, the influence of the collector distance from the electrode and other influences of the construction parameters were simulated. These simulations are mentioned in the following chapters. Autodesk Simulation Mechanical software was used to simulate the electrostatic field using the finite element method.

2. EXPERIMENT

To determine the values of critical stresses, an experimental device for the production of nanofibres using a wire electrode was used. **Figure 1** shows the scheme of the used device. The principle is based on a wired vertical electrode which is rewound from the spool 3 on the spool 8. For motion for spool 8 is used a stepping motor 9. The polymer solution is supplied to the wire via the dispenser 4. Due to the upward winding of the wire, the polymer solution is uniformly applied to the surface of wire. A DC high voltage is connected to the wire 6. The nanofibres produced on the electrode are

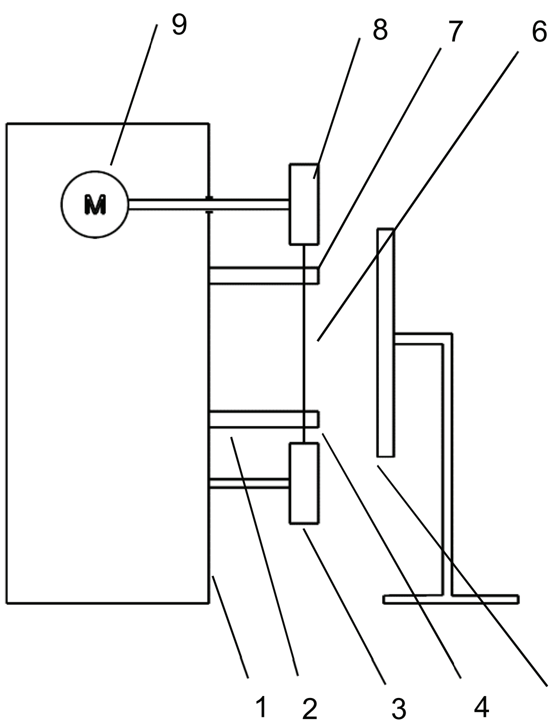

Figure 1 scheme of experimental device

deposited on the collector 5. The individual critical stresses for the respective strings were read out by the display of the measuring voltmeter. The creation of the first nanofibers was observed through the hi-speed camera and at that moment the voltage value was subtracted. These measurements were made for several strings and the average value was determined. The resulting values are shown in **Table 1**.

3. SIMULATIONS

3.1. Critical electric field

For the critical stresses obtained from the experiments, simulations were performed, from which the values of the respective critical intensities were read. **Figure 2** to **Figure 4** show the results of simulation of the voltage distribution and the intensity of the electric field around of the circular string electrodes of the shapes described in the previous paragraph. The simulations were performed for the critical stresses associated with individual strings. The collector always has a voltage of -10 kV. The individual values of the critical voltages are written in **Table 1**.

Table 1 critical electric field

Shape of string	Star Ø 1.3mm	Circle Ø 1.3mm	Circle Ø 2mm
Voltage - string elecrode U_1 [kV]	22.25	23	26
Voltage - colector U_2 [kV]	-10	-10	-10
Electric field [V/mm]	5971	5646	4690

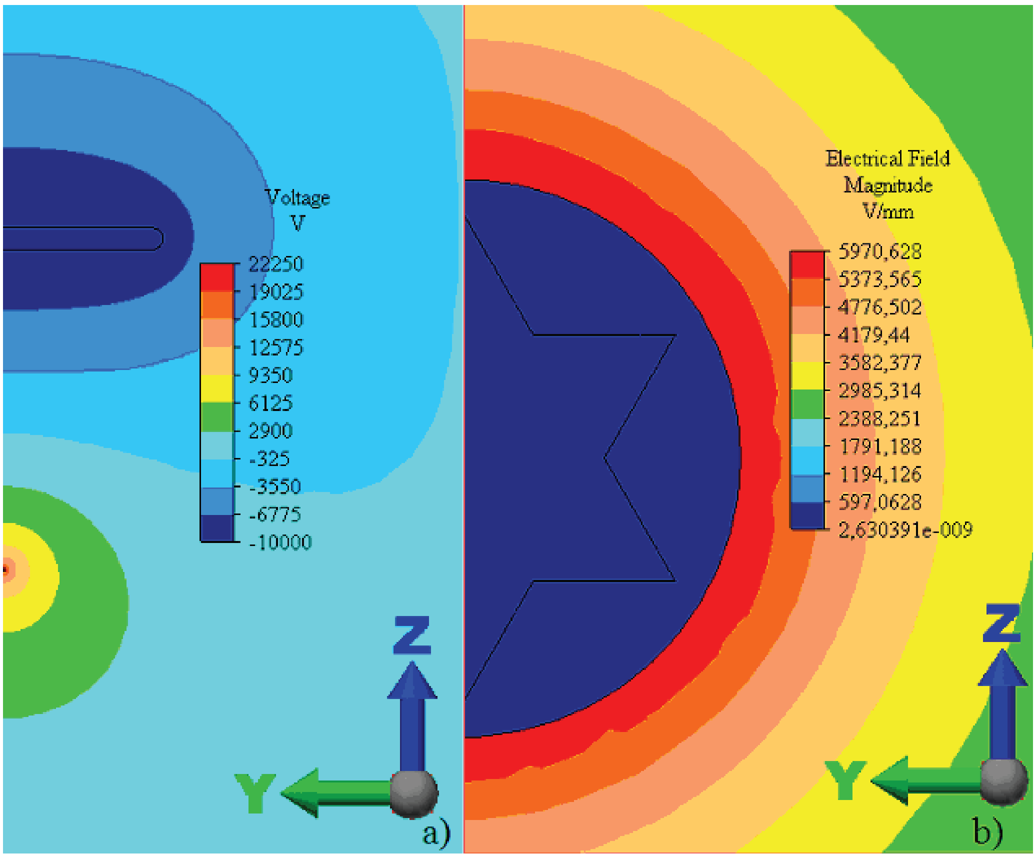

Figure 2 Results of simulation for star-shaped string, Ø 1.3mm

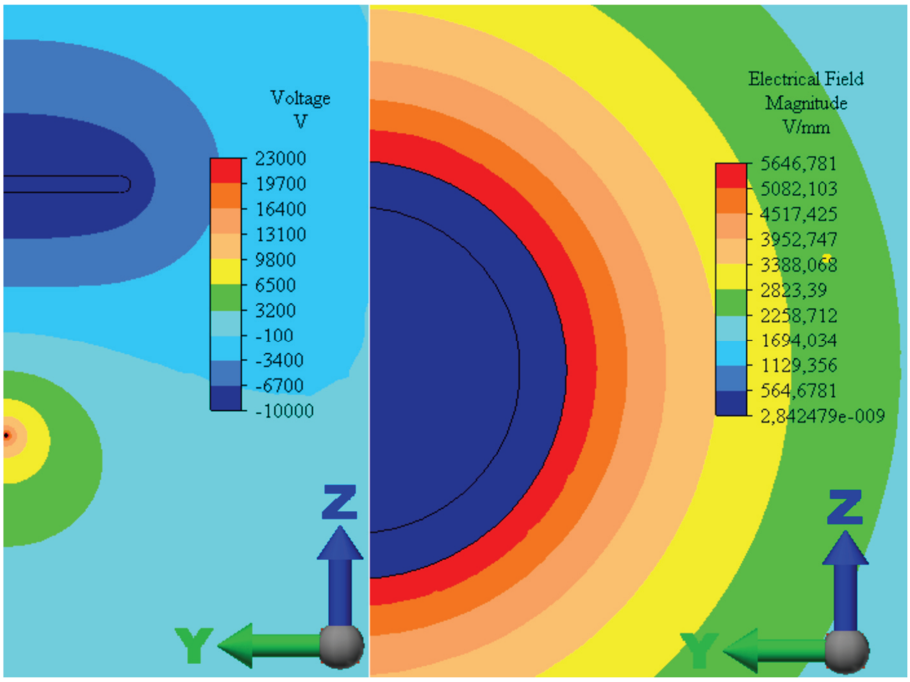

Figure 3 Results of simulation for circle-shaped string, Ø 1.3mm

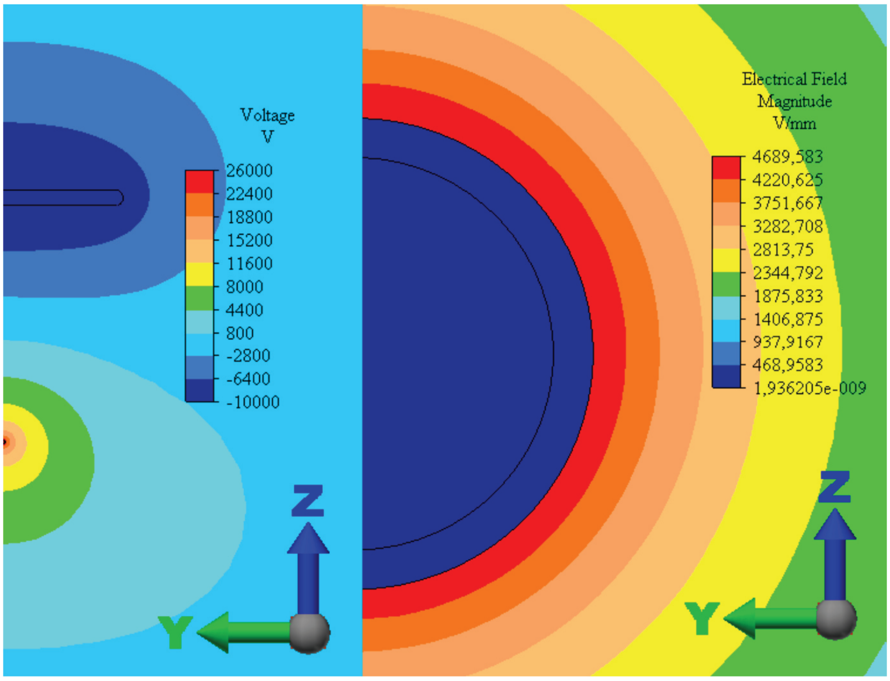

Figure 4 Results of simulation for circle-shaped string, Ø 2 mm

3.2. Influence of polymer layer to electric field

One of important factor influencing the electric field is also the layer of polymer solution on the surface of the string. With a constant dosing of the polymer and the faster unwinding of the string, the string is filled less and vice versa. This is reflected by the size of the layer or the diameter of the polymeric container. Simulations were made for a 1.3 mm diameter circular string with different diameters of the polymeric layer. These diameters of polymer layer were observed during experiments by hi-speed camera for each string. The results of simulations are shown in **Table 2** and also processed in the graph in **Figure 5**

Table 2 critical electric field

Diameter of string [mm]	1.3		
Voltage - string [kV]	23		
Voltage - collector [kV]	-10		
Diameter of polymer layer [mm]	1.46	1.56	1.66
Electric field [V/mm]	6072	5764	5647

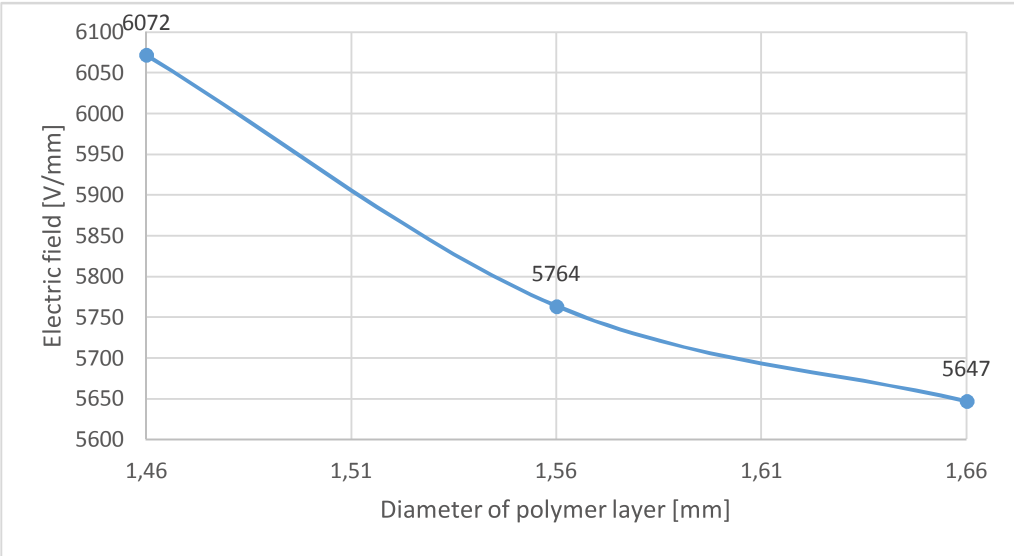

Figure 5 influence of polymer layer to electric field

3.3. Influence of distance between string electrode and collector

The last simulation was focused to analyze the effect of the distance of the string from the collector to the value of electric field on the surface of the polymeric package. The collector distance is gradually changed from 100mm to 250mm. The results of the analysis are given in **Figure 6**.

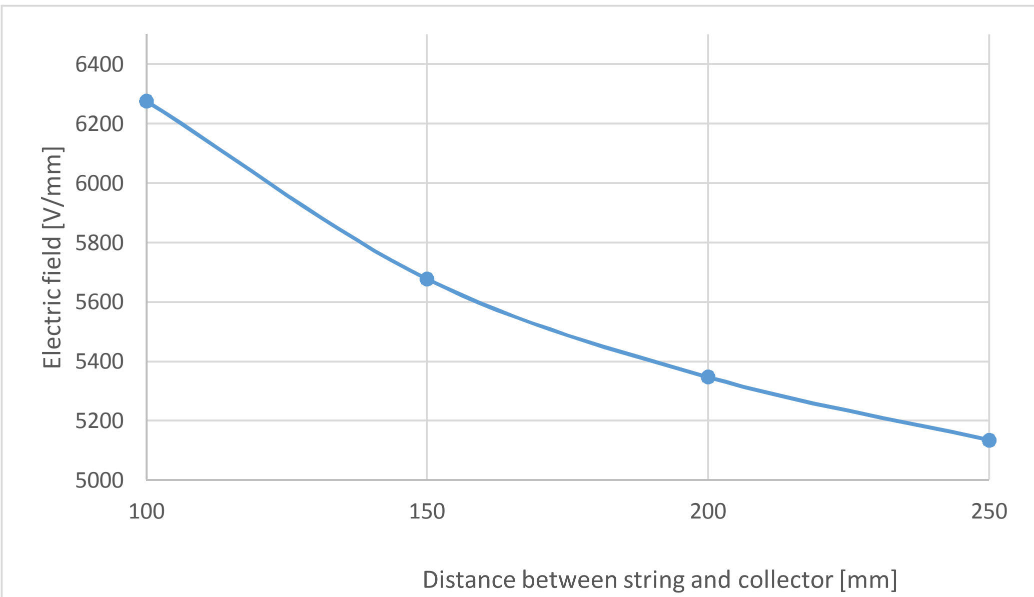

Figure 6 influence of polymer layer to distance between string and collector

4. CONCLUSION

The results show that the highest critical intensity is for a star-shaped string with a diameter of 1.3 millimeters. It is also important that this intensity value arises at a critical voltage of 22 kV, the lowest measured value of the critical voltage across all tested electrodes. From this it can be concluded that the best version of the spinning string is the string with a cross section of the star. It can also be concluded that using this type of string will be the highest productivity of the production of nanofibers. Further, it was found that the lower filling of the string with the polymer solution was higher on the surface of the string. This could also could be used to increased production of nanofibers.

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