ANALYSIS AND OPTIMIZATION OF THE BALL SHAPED ELECTRODE DESIGNED FOR THE AC-ELECTROSPINNING

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Abstract

The paper deals with the analysis and optimization of spinning electrode designed for the nanofiber spinning method using an alternating electric current. The optimization was based on the simulation of distribution of electric field according to the shape of the spinning electrode by using the finite element method. The intensity of electric field has a major influence on the electrospinning and subsequently on the resulting structure. The aim of the optimization was to reach uniform distribution of electric field on the electrode surface by changing the number of design parameters. Based on these analyses, a new shape of the spinning electrode was designed, which offers uniformity of the electric field intensity around the whole operative surface of the spinning electrode and provide the same physical conditions which are important for the electrospinning. This leads to the electrospinning stabilization, which affects the quality of the resulting nanofiber structure.

Keywords: Electric field, electrospinning, spinning electrode, electrostatic analysis

1. INTRODUCTION

The principle of free-surface production of nanofibers using a direct electric current, which has been developed in the Technical University of Liberec [1], has been known for several years and widely used in industry. A new electrospinning principle (called "AC Electrospinning") has been developed recently, which uses an alternating electric current to produce nanofibers. The benefit of this method is that two oppositely charged electrodes are not needed for spinning, since a virtual collector is formed around the spinning electrode through oppositely charged ions [2], [3]. An important step to apply the AC Electrospinning in industry is to develop new types of electrodes that will be used to produce nanofibers with the parameters corresponding to the relevant application.

The paper deals with the design and optimization of spinning electrodes for AC Electrospinning, in terms of uniform intensity distribution of electric field. The intensity of electric field on the electrode surface has a major influence on the spinning process and subsequently on the quality of the resulting structure of nanofibers [4]. The aim of the design of a new shape of the electrode is to reach uniform intensity distribution of electric field on the operative surface of the electrode. Uniform intensity distribution will result in comparable conditions on the whole electrode surface, which are necessary for the spinning process. This leads to nanofibers with comparable fineness.

2. BASIC ELECTRODE

Currently, when the development of the new spinning method and its application are in the early stages, simple basic types of electrodes are used. **Figure 1a)** shows a photograph of a basic electrode, which is used to test the AC Electrospinning process. The basic of the electrode is a tube with a conical head at its end, the shape of which is designed so as to have the maximum intensity of electric field at the circumferential edge. A polymer solution flows through the electrode to the head surface, where nanofibers are formed in places with intensity that exceeds the critical limit. The spinning process takes place at electric voltage 25 - 40 kV of alternating voltage, which is applied to the spinning electrode.

Figure 1 Basic electrode

Simulations of distribution of electric field on the basic electrode were carried out using the Autodesk Simulation Mechanical software, which contains a module for the calculation of electrostatic field using the finite element method. With respect to geometry and marginal conditions, the calculation model was simulated as rotationally symmetric job. All jobs were simulated for electric voltage on the electrode of 25 kV. The **Figure 2** shows the result of one of the simulations. It shows that the intensity at the edge of the electrode is at its maximum level. It is evident that the intensity all over the surface of the electrode head is distributed non-uniformly and thus the same conditions for spinning process are not provided all over the surface.

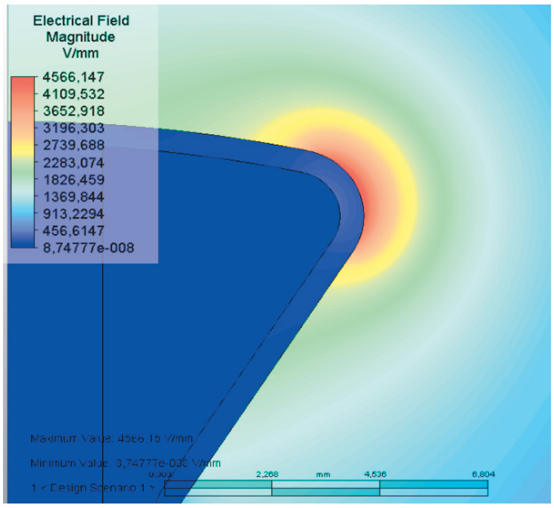

Figure 2 Distribution of intensity on the surface of the basic electrode

3. DESIGN OF A NEW SHAPE

Following the previous analyses, how to modify the shape of the electrode head so as to reach uniform distribution of intensity of electric field on its surface was considered. A shape of a ball seemed to be the most appropriate, because the intensity on the surface of the ball under ideal marginal conditions should be equal at all points. The analyses show that the intensity on the surface of the ball from the top to the ball gradually declines. This is because the tube disrupts the symmetry and affects the distribution of intensity on the surface of the electrode head. Depending on this finding, the shape was modified by changing R1, R2, R3 radii, which are shown in the **Figure 3.** The individual values of radii were always changed so that their value towards the tube declines. It is because the intensity grows with declining radius. This should cause the declining intensity to compensate. Selecting an optimal combination of radii should lead to the uniform distribution of intensity of electric field on the electrode surface. Therefore, this combination was searched for by means of a set of analyses with different combinations selected.

The **Figure 4** shows the result of the analysis of the final shape of electrode. It is evident that the selected combination of radii will lead to the uniform distribution of intensity on the surface of the electrode head.

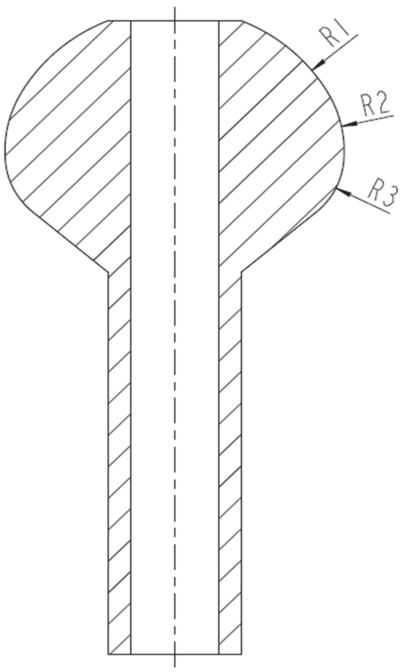

Figure 3 New shape

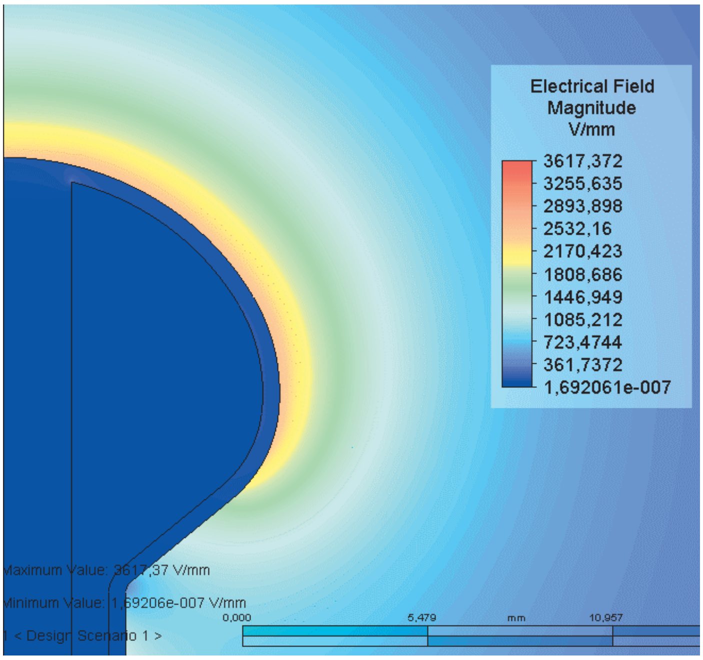

Figure 4 Analysis of the optimized shape

4. CONCLUSION

The graph in the **Figure 5** shows the comparison of distribution of intensity of electric field for two electrodes depending on the distance from the top of the electrode head. The red curve corresponds to the values for the basic electrode; the blue curve corresponds to the values for the new optimized electrode. The graph shows a significant difference between electrodes in terms of intensity distribution. The original electrode shows a great non-uniformity of intensity distribution and it may be expected that the conditions for spinning are not optimal. For a new shape of the electrode, uniform intensity distribution of electric field on the surface of the electrode head was reached. It can therefore be concluded that there will be the same conditions for the spinning process all over the surface

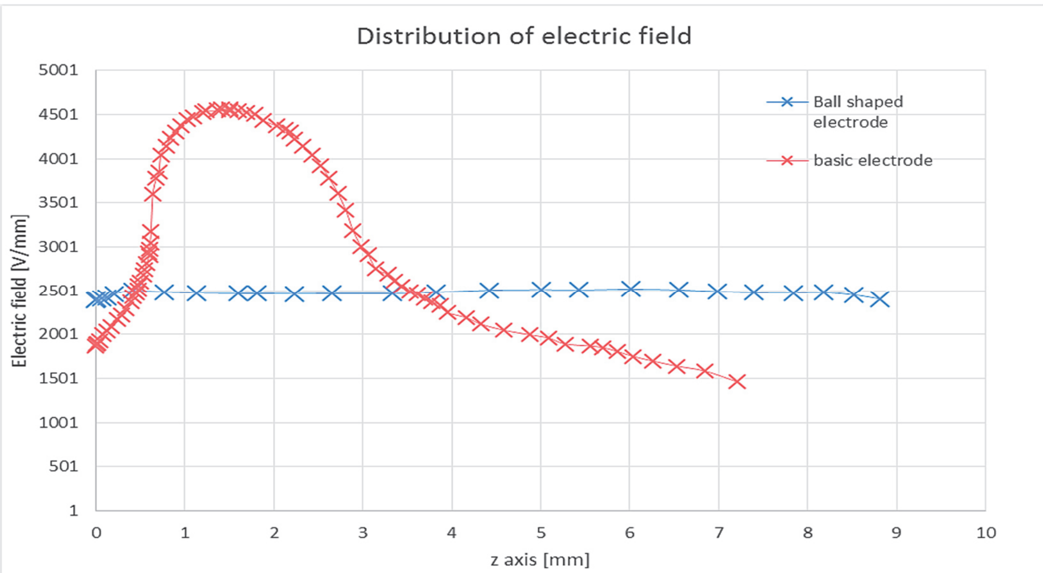

Figure 5 Comparison of electrodes

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