MEASUREMENT OF ELECTRIC CURRENT DURING ELECTROSPINNING

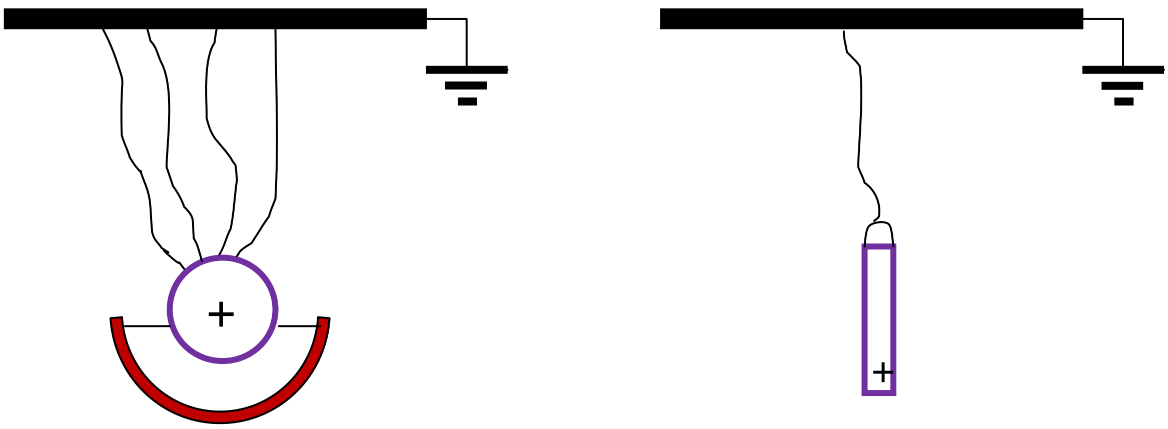
Pavel POKORNÝ, Oldřich JIRSÁK
Technical University of Liberec, Faculty of Textile Engineering, Department of Nonwovens, Liberec, Czech Republic
pavel.pokorny@tul.cz

Abstract
Here we report on the measurement method of electric current during electrospinning process. Measurement of electric current during electrospinning was suggested by Rutledge [3, 4] as a method to study electrospinning mechanism. The method was adapted for investigation of the time course of electric current with oscilloscope. The oscilloscopic record is compared with the image of the moving polymer solution and formation of liquid jet and nanofibers.

Key words: electrospinning, measurement of electric current, nanofibers, liquid jet,

Introduction

Electrospinning is a method of producing sub-micron fibers. In the electrospinning process, polymer solution or polymer melt is formed into thin fibers in electric field.
Various electrospinning techniques have been described in papers, namely needle and needleless process. In the needle electrospinning [1], a charged polymer solution is pumped through a hollow needle. Sub-micron fibers are formed between the tip of the needle and a grounded collector electrode creating a layer on the latter. In the needleless electrospinning [2], Taylor cones are created on the surface of polymer solution. Typically, the polymer solution is placed on the surface of a slowly rotating metal roller partly immersed in a reservoir (Fig. 1 a). Many Taylor cones are created on the surface of the roller (typically 5,000 – 50,000 per square meter) which gives a high spinning throughput and makes the process industrially interesting. In a laboratory scale, needleless electrospinning can be profitably studied using a metal rod as a spinning electrode (Fig. 1 b). If the diameter of the metal rod (and that of polymer solution droplet) is greater than 8 mm, 1 – 6 Taylor cones occur on its surface or circumference. Only one Taylor cone usually occurs if the rod diameter is 3 mm or less.



a) *b)*

Figure 1. Needleless electrostatic spinners. A roller spinner (a) and a rod spinner (b)

Measurement of electric current during electrospinning was suggested by Rutledge [3,4] as a method to study electrospinning mechanism. The authors measure voltage on a resistor 1.0 MΩ using a digital multimeter Fluke 85 III. The voltage is converted into current using Ohms law. Volume charge density in the polymer jet is expressed as I/Q, where I is measured current and Q is flow rate.
It is the aim of present work to measure electric current in polymer jets during needleless electrospinning process, to analyse it and to discuss relations between the current and the mechanism of electrospinning .

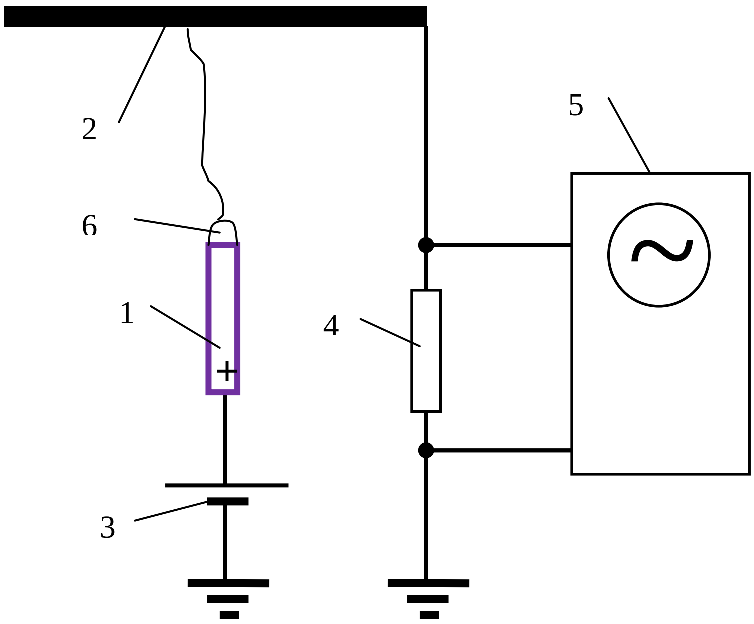


Figure 2. Experimental setup.

Experimental

Laboratory spinning device including the measuring circuit is shown in Fig. 2. It consists of a steel rod (1), diameter 3 mm, as a spinning electrode, and a steel collector electrode (2). Spinning electrode is linked with a source of high voltage (3). Collector electrode is grounded through a resistor adjustable to 10 – 100 kΩ (4). Voltage is measured on the resistor using a memory oscilloscope (5). Current is calculated using Ohms law.
Measurement consists of following steps: A droplet of a polymer solution (6) is placed on the spinning electrode. High voltage is switched on. In the initial stage, only the current is measured corresponding to conductivity of ionized air. After a Taylor cone is developed on the surface of the droplet, the current increases and a trigger automatically initiates its recording. The development of the Taylor cone needs the time between several hundreds of second to several seconds. A typical record of the electrospinning of a spinnable polymer solution is shown in Fig. 3.
The current in the course of time is compared with Taylor cone development and the jet development from high-speed camera in (Fig. 4).

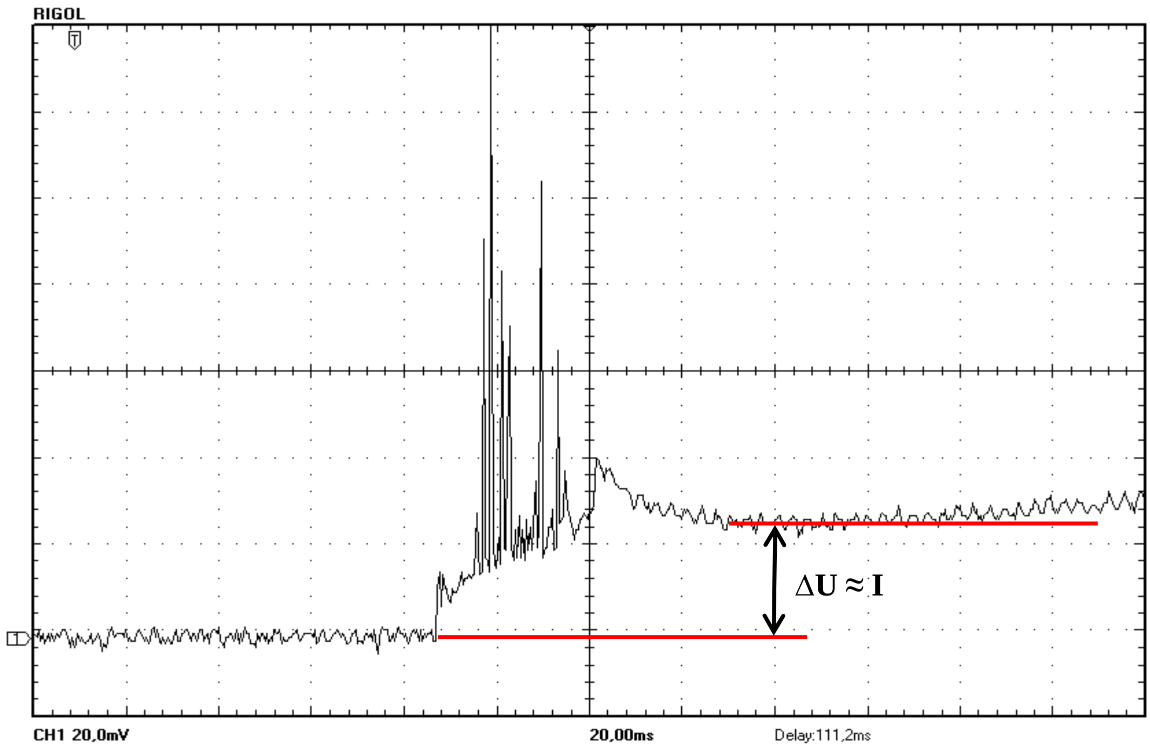


Figure 3. A typical record of the current during electrospinning of a spinnable polymer solution

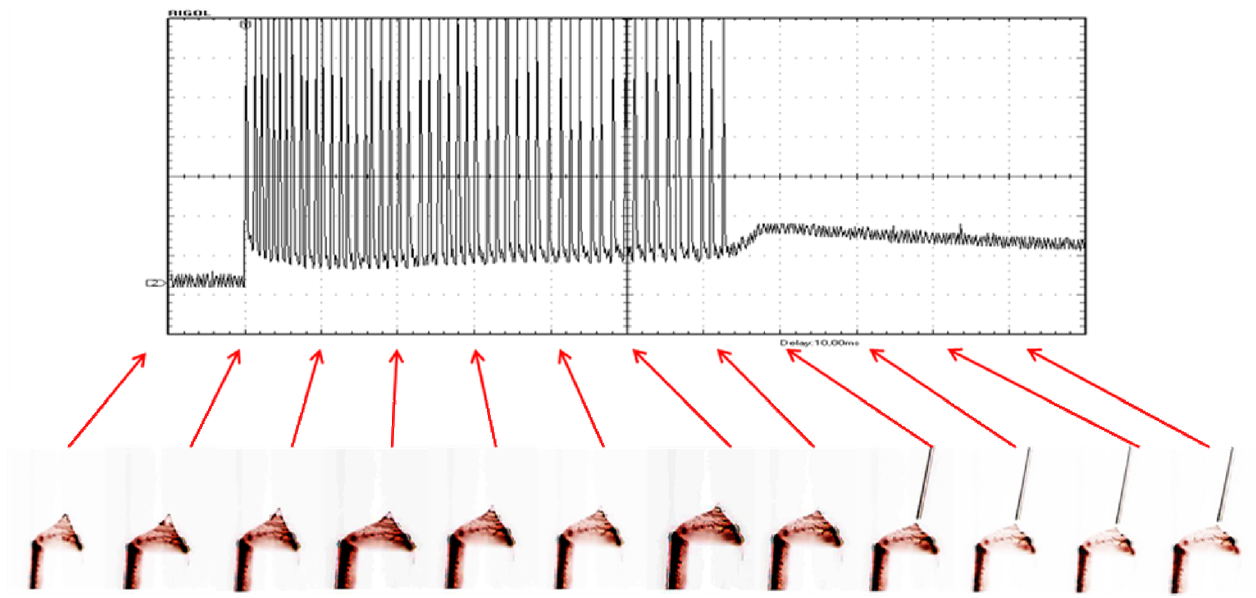


Figure 4. The time dependent current is compared with Taylor cone development and the jet development from high-speed camera.

Conclusion

Movement of charged substance is shown as an image of electric current on oscilloscope. This record shows the motion of substance in time. The peaks on the start of record are the same as those of corona discharge. The rise time of the start edge is about 10^{-7} seconds in corona discharge as well as in electrospinning. The electric current in liquid jet corresponds to the work needed to create nanofibers and their transport towards the collector.

Acknowledgements

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