subject to further studies and technology development.

Within a very short period of testing different polymer solutions we achieved significant benefits of optical monitoring. The lifespan of the single fibers jet was measured with the optical according to set conditions. There was observed very short lifetime for some kinds of PVDF polymer (0.7 sec), or conversely very long life for PA6 (about 7 seconds), which is one of the most stable systems.

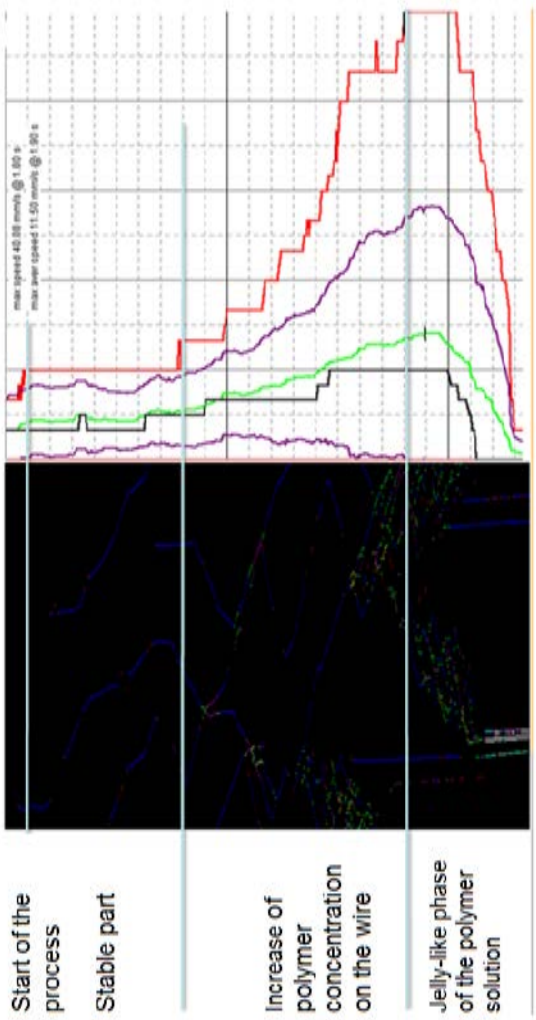


Fig. 17 Jet motion analysis using graph theory. The map is a horizontally displayed position on the string and a vertical (top-down) time scale. On the right, the velocity of jets movement over time is analyzed by different methods.

There cannot be described the polymer jet behavior with simple quotation just based on the variable constants according to these experiments. There has to be provided complex system analysis and signal processing that can be generalized with quotation but with variables set to individual polymeric solution. These data can be obtained from the signal processing as frequency characteristic. These data are suggestive to increase the frequency of recovery solution (the set of flow allows 1.0 s - 1.5 s, according to the width of the machine) and for adjusting the formulation (composition of the solution, process control) to extend the life. The acquired data specifying the knowledge gained long-term subjective observation.

Furthermore, there was set the correlation between viscosity and changes in the form of liquid on the wire electrode. Obviously solutions of low viscosity are readily converted into droplets, whereby the curvature of the liquid improves the stability of jets, if droplets are not too large. Very stable position of jets (exhibits minimal movement and deviations) we see again on PA6, and PVDF. Unstable are viscous polymer solution such as PUR.

Microanalysis of shape of jets is currently limited with resolution of the inspection system, because of low magnification. With the development of analytical system we expect algorithmic improvements also focused on the emergence of jets from a larger volume drops. The volume changes would be linked with yield and product characteristics of the process, and fiber diameter in theory.

## 4 Conclusion

Here were shown visualizations of an experimental spinning device. There have been selected polymer solutions to observe changes with increasing excitation voltage on the wire. The scene lighting used LED light source, providing high light intensity and negligible thermal influence in two regimes of light setup.

The visualizations have to be analyzed using image processing to identify and subsequently quantified. There are more characters that require further analysis: density and spacing of the cones with spouted solution geometry, cones themselves, the length of the steady region, shape of branching and subsequent splitting.

The illumination using white light enables to observe the light scattering on the jets and separation part. This diffracted light and colors could be used for fiber diameter detection. The analysis of single jet, angles of whipping or branching will be the next step in research. For all these observations mathematical description would be created, so that different parameters could be stored in datasets.

The authors gratefully thank to the support of Technology Agency of the Czech Republic (TA ČR) TA04011086 - Opto-electronic system for quality control of nanofiber materials production,

and LO1201 co-funding from the Ministry of Education, Youth and Sports as part of targeted support from the „National Programme for Sustainability I".

*References:*

[1] D. H. Reneker, A. L. Yarin, Electrospinning jets and polymer nanofibers, *Polymer* 49, 2008, pp. 2387-2425.

[2] N. Bhardwaj, S. C. Kundu, Electrospinning: A fascinating fiber fabrication technique, *Biotechnology Advances* 28, 2010, pp. 325-347.

[3] D. Nurwaha, X. Wang, Free Surface Electrospinning: Investigation of the Combined Effects of Process Parameters on the Morphology of Electrospun Fibers, *Fibers and Polymers* 16, 4, 2015, pp. 850-866.

[4] K. M. Forward, A. Flores, G. C. Rutledge, Production of core/shell fibers by electrospinning from a free surface, *Chemical Engineering Science* 104, 2013, pp. 250-259.

[5] K. M. Forward, G. C. Rutledge, Free surface electrospinning from a wire electrode, *Chemical Engineering Science* 183, 2012, pp. 492-503.

[6] Elmarco s.r.o., Method for application of liquid polymeric material onto spinning cords and a device for production of nanofibers through electrostatic spinning, WO/2012/139533, 10.18.2012.

[7] X. Yan, M. Gelvelber, Investigation of Electrospun fiber diameter distribution and process variations, *J. of Electrostatics* 68, 2010, pp. 458-464.

[8] Y. Cai, M. Gelvelber, The effect of relative humidity and evaporation rate on electrospinning: fiber diameter and measurement for control implications, *J Mater Sci*, 2013, pp. 1-15.

[9] N. I. Kolev, *Multiphase Flow Dynamics 2*, Springer Berlin Heidelberg New York, 2007.

[10] A. L. Yarin, Bending instability in electrospinning of nanofibres, *J. Applied Physics*, 89, 5, 2001, pp. 3018-3025.

[11] M. Cloupeau, B. Prunet-Foch, Electrohydrodynamic spraying functioning modes: a critical review, *J. Aerosol Sci* 25, 6, 1994, pp. 1021-1036.

[12] Y. Cai, M. Gevelber, The effect of relative humidity and evaporation rate on electrospinning: fiber diameter and measurement for control implications, *J. Mater. Sci.*, 48, 22, 2013 pp. 7812-7826.

[13] D. Lukas, A. Sarkar, P. Pokorny, Self-organization of jets in electrospinning from free liquid surface: A generalized approach, *J. Appl. Phys.*, 103, 2008.