EAN 2012
50th annual coference on experimental stress analysis

Macro Mechanical Testing of Nanofibers: Tensile Strength

Pavel Tesárek[1], Václav Nežerka[2], Richard Ťoupek[3], Tomáš Plachý [4] & Pavla Ryparová[5]

Abstract: Macro-mechanical properties are lately investigated even in case of nano-materials, e.g. tensile strength is material properties for characterization of the nanofiber. In a similar way like the nanofibers weight per unit area correlates with water vapor diffusion permeability it is presumable that the tensile strength (in combination with e.g. weight per unit area) is related to certain macroscopic and/or microscopic properties that can be efficiently used for the passportization. In this paper, initial nanofibers testing of the macro-mechanical property – tensile strength (pull test), is presented. Tested nanofibers were based on Poly-(lactide-co-glycolite) acid (PLGA).

Keywords: Nanofibers; Tensile Strength; Mechanical Properties

1. Introduction

The mechanical test of nanofibers can be performed using conventional testing techniques [1]. For the macro-mechanical testing there were used nanofibers based on Poly-(lactide-co-glycolite) acid (PLGA). Such nanofibers are largely used, for instance, in biomedicine applications [2].

The electrospinning technology enables production of nano fibers within a certain range of weight per unit area. Using this technology it is possible to produce nanofibers with the width of up to 4 meters. The produced nanofibers, depending on the weight per unit area, can be applied with or without supporting material (spunbond). The nanofibers are macroscopically hardly accessible and so just the reproducibility of the same nanostructure in repeatable production procedure is a very delicate problem [1].

[1] *Ing. Pavel Tesárek, Ph.D.; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic; tesarek@fsv.cvut.cz*
[2] *Ing. Václav Nežerka; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic; vaclav.nezerka@fsv.cvut.cz*
[3] *Ing. Richard Ťoupek; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic; richard.toupek@fsv.cvut.cz*
[4] *Ing. Tomáš Plachý, Ph.D.; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic;plachy@fsv.cvut.cz*
[5] *Mgr. Pavla Ryparová; Department of Civil Engineering, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic; pavla.ryparova@fsv.cvut.cz*

The above mentioned facts tend to the need for investigation of macro-mechanical properties. Besides there are other mainly macroscopic properties (especially the weight per unit area) that can specifically describe the micro structure of nanofibers. Such properties are subsequently used for passportization of nanofibers, i.e. an easy and cheap method how to check the microscopic properties of produced nanofibers based on measured macroscopic properties.

In the next step, it is proposed to move the nanofibers testing into micro-level, e.g. using AFM (Atomic Force Microscopy) and nanoindentation devices [3].

2. Testing arrangement and tested samples

The tensile strength tests were carried out on LabTest 4.100SP1 device at the Faculty of Civil Engineering of CTU in Prague. The measuring range was set to 50 N maximum where the accuracy exceeds 0.1 % (at 2 N force).

The PLGA based nanofibers were spun in the Center for Nanotechnology in Civil Engineering, at the Faculty of Civil Engineering, Czech Technical University (CTU) in Prague. This center uses Elmarco laboratory version of elestrospinning device based on Nanospider technology, in this case the NS Lab 500 S was used for preparing of the PLGA nanofibers.

The PLGA solution for electrospinning was prepared as 2.3% concentrate where 0.23 g of PLGA was stirred with 4 ml of dimethyl chloride and subsequently 6 ml of dimethylformamide were added [4]. Nanofibers were produced with the width of 500 mm; 50 mm from this width were cut out on the both ends of the nanofibers because this area is not homogenous.

The tested samples with the length of 40 mm and width between 20 and 25 mm were cut out from the PLGA based nanofibers. The nanofibers layer was subsequently carefully separated from the polymeric support textile (spunbond). The samples' weights per square meter were determined from their dimensions and weights.

The ends of tested samples were strengthened by a paper tape to prevent damage of the PLGA nanofibers. It is the method which is commonly used for these materials. From the practical view, the testing was done on the specimens with the weight about 3 g/m^2 which were good workable. On the other hand some specimens were damaged during their preparation. For example, it is not possible to detach the paper tape from the nanofibers without its damage. Fig. 1 shows the arrangement of the tensile strength.

3. Experimental results

Fig. 2 presents typical result of the tensile test – the dependence of displacement on tensile force. The resulting tensile forces were unified by dividing them by the width of the sample (N/m). The delay of loading can be seen in the graph which is caused by correct placement of the specimen in the jaws of the press. The problem is the placement of the specimen to be equally placed – stretched – between jaws. In other case the wrinkling of the specimen occurs and the resulting date will be distorted.

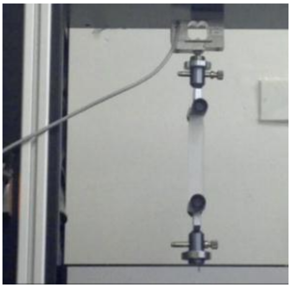

Fig. 1. Arrangement of tensile test with a tested sample

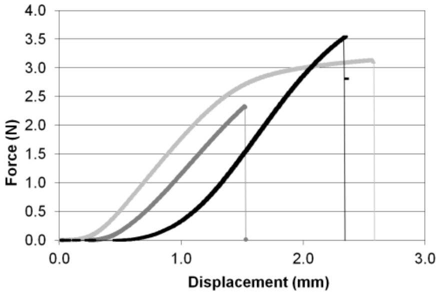

Fig. 2. Typical dependence of displacement on force for tested PGA nanofibers.

Table 1 shows obtained experimental results. For the weight per square meter of 2.87 to 3.28 (± 10 %) g/m^2 the resultant force reaches 6.87 to 7.65 10^{-5} (± 10 %) N/m. The results were determined as the arithmetic mean of 6 measurements.

Table 1. Obtained experimental results

Weight per square meter (g·m^{-2})	Force per width (10^{-5} N·m^{-1})
3.05	6.87
3.10	7.65
2.87	7.45
3.28	7.35
3.17	7.23
3.12	7.48

4. Conclusions

From the practical point of view it is possible to work with polymeric nanofibers that have weight per unit area more than 1 g/m^2. Practical working with nanofibers with lower weight per unit area is very complicated because of the nanofibers surface tension when the nanofibers tend to wrap up.

Other aspect is a treatment of the nanofiber sample ends that must be strengthened before fastening in the jaws of a testing machine [5]. The nanofibers tensile strength testing showed the feasibility of such a testing. There are certain critical aspects limiting the testing of nanofibers on common equipment (pull test devices).

The first experiments clearly show that even in this area it is necessary to resolve the preparation of the specimens and also their testing. For the future, we want to integrate two inductive displacement transducers to the measuring system (one from each side of the specimen) to get more accurate information about jaws movement.

Acknowledgements

This outcome has been achieved with the financial support of the Grant Agency of the Czech Republic – P108/12/0891 and the Czech Technical University in Prague – SGS12/117/OHK1/2T/11.

Special thanks belong to the Center for Nanotechnology in Civil Engineering at Faculty of Civil Engineering of Czech Technical University in Prague where the nanofibers production and testing was carried out.

References

[1] Huang, L., Nagapudi, K., Apkarian, R. and Chaikof E.L. ,"Engineered collagen-PEO nanofibers and fabrics." *J Biomater Sci Polym Edn*, 12, 9, 2001, pp. 979-984. ISSN 0920-5063.

[2] Paipitak, K., Pornpra, T., Moingkontalanf, P., Techitdheer, W. and Pecgarapa, W., "Characterization of PVA-Chitosan Nanofibers Prepared by Electrospinning." in *Procedia Engineering, The 2nd International Science, Social Science, Engineering and Energy Conference 2010* (I-SEEC 2010), 2010, pp. 101-102. ISSN 1877-7058.

[3] Tesárek, P. and Němeček, J., "Microstructures and micro-mechanical study of gypsum", *Chemické listy*, 105, 17, 2011. pp. 852-853. ISSN 0009-2770.

[4] Andrady, L. A., *Science and* technology *of polymer nanofibers*, New Jersey 2008, pp. 407. ISBN 978-0-471-79059-4

[5] Li, W.J., Laurencin, C.T., Caterson, E.J., Tuan, R.S. and Ko, F.K., "Electrospun nanofibrous structure: A novel scaffold for tissue engineering." *J Biomed Mater Res*, 60, 4, pp. 613-621. ISSN 1552-4981.