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Mechanical Properties of Stabilized and Non-stabilized Poly (vinyl-alcohol) Nanofiber Textiles

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Abstract. Tensile strength, as the basic macro-mechanical property, was tested using the conventional methods on a high-sensitivity testing frame. The testing methodology for the Poly(vinyl-alcohol) (PVA) stabilized and non-stabilized nanofiber textile specimens was similar to the ones used in the case of thin-layered or textile materials. The loading of the samples was carried out using LabTest 4.100SP1 device, equipped by the load cell having the measuring range up to 50 N to obtain accurate results about tensile strength and stiffness. The experiment was displacement controlled by the loading rate of 0.2 m/s. The testing was carried out in common laboratory conditions on both materials, each represented by more than 6 samples of dimensions 100 mm × 20 mm. The results indicate that the stabilized samples exhibit higher strength but their ductility is significantly lower than in the case of non-stabilized nanofiber textiles.

Introduction

Nanofiber textiles are mostly used in medicine and textile industry. However, the recent research indicates a possibility of their use in civil engineering as vapor barriers or, when treated, as prevention against the growth of fungi and microorganisms. Such treatment might be accomplished by incorporation of ions or nanoparticles. Such problems could be avoided if the nanofibers produced by means of needleless electrospinning were used. The vapor diffusion parameters of such materials can be continuously changed, which is the main aim of the proposed project. If we consider the use of nanofibers in the construction industry, e.g., in the above described application, there would appear an interaction of two completely different types of materials, not only in size (scale) of these materials, but also with respect to their material properties. It is well known, that the nanomaterials have different material properties from the materials having the same composition, but produced in macro-scale by a conventional methods and technologies [1]. Nanoparticles spread in a polymer matrix are nowadays used as various filters. New types of such membranes enable even more perfect and faster selection of molecules, paradoxically the bigger ones more easily. The separation of molecules is then utilized in biological water treatment, desalination of sea water, in ecological application or in oil industry [2,3].

Tested Materials

The PVA polymer solution for electrospinning was prepared from the following components: 375 g of PVA (Sloviol 16%), 117 g of demineralized water, 4.4 g of glyoxal, 3 g of phosphoric acid (75%) used as cross-linking agents [1]. PVA based nanofibers were spun using Nanospider elestrospinning device (NS Lab 500S) at common laboratory conditions (temperature of 23 °C and relative humidity of about 40 %). The polypropylene (PP) supporting base (spun bond) was enhanced by an antistatic treatment.

The PVA-based nanofiber textiles were subjected to tension on commonly used loading frame; the first one (A) was stabilized while the other set (B) was not. The specification of samples, their weight per unit area and mechanical properties are summarized in Tab. 1. The ends of the samples were reinforced by an adhesive tape to prevent their damage prior to the testing (Fig. 1). The stabilization (crosslinking) of produced PVA nanofibers was accomplished by the exposure to elevated temperature [2, 3]. During the stabilization process, the nanofiber textiles were exposed to 140 °C for the time of 10 minutes [1, 12]. Such approach combines the physical (elevated temperature) and chemical stabilization due to the presence of chemical additives. The connection of individual PVA fibers in nodes can be observed in Fig. 1.

Table 1. Properties of the tested samples.

Set	Weight per area [g/m^2]	Stiffness [Nm/g]	Maximum elongation [%]	Tensile strength [Nm/g]
A	3.25 ± 0.17	643 ± 16	8.19 ± 1.91	21.6 ± 3.2
B	4.12 ± 0.21	765 ± 8	16.31 ± 3.18	18.8 ± 4.3

Experimental Methods and Results

The weight per unit area was determined for all samples based on their weight and measured dimensions. Tensile strength, as the basic macro-mechanical property, was be tested using the conventional methods on the machine with the highest sensitivity – LabTest 4.100SP1 device, equipped by the load cell having the measuring range up to 50 N [10]. The methodology of testing was similar to the one used in thin-layered or textile materials [11].

The experiment was displacement controlled by the loading rate of 0.2 m/s. The testing was carried out in common laboratory conditions (temperature of 23 °C and r. h. of about 40 %). The tensile strength and stiffness was tested on both materials, each represented by more than 6 samples. The clamps in the testing machine were 25 mm wide, ensuring a uniform stress distribution over the specimen width [10].

The specimens were carefully clamped into the machine and centered to avoid non-uniform loading, Fig. 2. The values of tensile strength and stiffness (both expressed in Nm/g), presented in Tab. 1, are related to a unit meter of width and 1 g of weight per unit area. This allows a proper interpretation of result and a comparison between individual configurations. It was found that the stabilized samples (A) are about 10 % stronger in tension but their ductility is about a half of the samples without stabilization (B). However, their ductility is significantly lower than in the case of non-stabilized textiles.

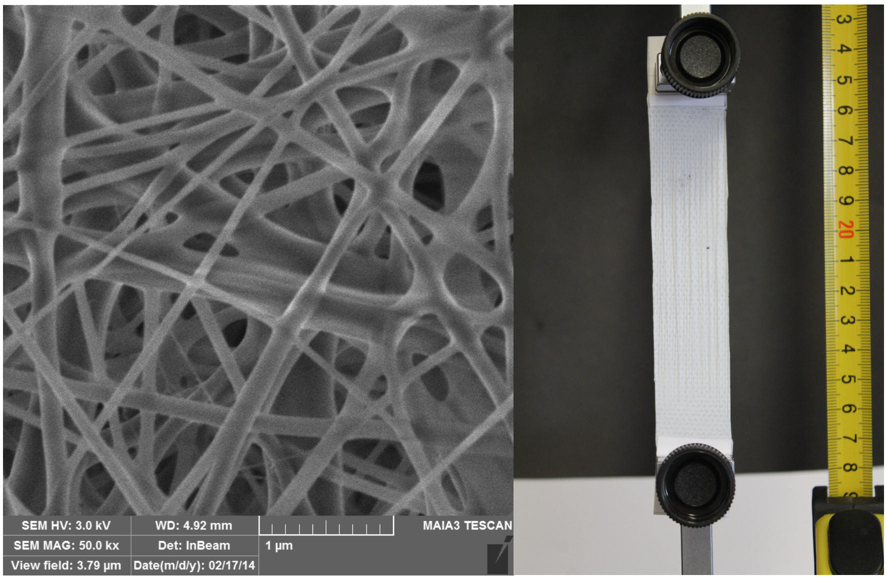

Fig. 1. SEM image of the stabilized nanofibers (left); tested samples during the testing (right).

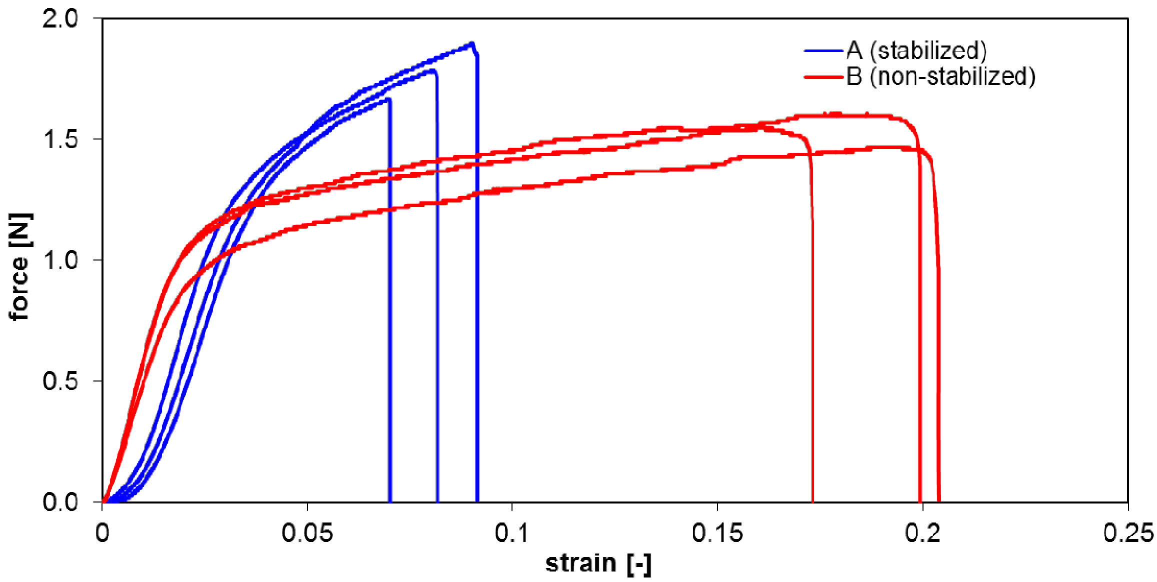

Fig. 2. Stress-strain diagram obtained by the testing of nanofiber textiles in tension.

Conclusions

Based on the presented results, it can be concluded that the stabilization (crosslinking) accomplished by means of physical-chemical process has a relatively big influence on the effective mechanical properties of the textiles at macro-level. The treatment of textiles by temperature around 140 °C results in the formation of a compact spatial nanofiber structure, which is reflected also on the macroscopic level and the different response to the tensile loading can be clearly seen on the stress-strain diagrams. The stabilized nanofiber textiles exhibit about 10 % higher tensile strength while their ductility is quite significantly lower.

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