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Tensile Strength and Stiffness of PVA-based Nanofiber Textiles with Incorporated Copper Ions

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Abstract. This paper is focused on the determination of mechanical properties of PVA-based nanofiber textiles produced by electro-spinning. The polymer solution used for electrospinning contained copper in the form of ions. The results of the tensile testing were compared with the results for the reference sample without additives. The results indicate that the addition copper ions cause an increase of the strength and stiffness.

Introduction

The future research in material engineering should be focused on the development of new technologies and improvement of materials used in the construction industry. For that purpose the nanotechnology could be more extensively used. There is the worldwide research of the development of new materials and the improvement of the mechanical properties of materials not only for construction industry [1] and except the enhanced mechanical properties the researchers often try to produce materials with other utility properties, such as antibacterial. To enhance both, we can consider an addition of metal ions [2], in particular copper [3].

Currently, the research deals mainly with the nanotechnology and nanofibers produced by electrospinning [4]. This technology enables a production of nanofibers within a certain range of weight per unit area and the fibers can be applied with or without supporting material (spunbond) [5]. The nanofiber-based materials produced by electrospinning are already used in bioengineering [6], or they are tested for the use as filters and protection of other materials [7].

It is necessary to provide the information about the nanofiber textile characteristic when usd for practical applications. We can use conventional testing techniques to investigate the mechanical properties of nanofiber-based materials [8] if it is important to know the tensile strength or stiffness of the nanofiber textiles [9].

Experiments

The tensile strength tests were carried out at the Faculty of Civil Engineering of the Czech Technical University in Prague.

Testing material was polyvinyl alcohol (PVA)-based nanofiber textiles with incorporated copper ions. The PVA based nanofiber textiles were spun in the Center for Nanotechnology in Civil Engineering, Czech Technical University (CTU) in Prague. Elmarco laboratory version of electrospinnig device based on Nanospider technology was used for the production of the nanofiber textiles, in particular the NS Lab 500 S device.

The basic solution for electrospinning was prepared as a combination of 10% (wt/V) PVA (Sloviol, Slovak Republic), 0.74% (wt/V) glyoxal, 0.3% (wt/V) Phosphoric Acid (Sigma-Aldrich, USA) and filled to half liter of distilled water. Phosphoric Acid and glyoxal were used as crosslinking agents that must be present in the solution for the subsequent stabilization of nanofiber textiles against water action.

Copper sulphate was used for the incorporation of copper ions into the raw polymer, in concentration 5 and 10 %, respectively.

The preparation of the samples was done at the temperature of 25°C and relative humidity of 45 %. The device for the electrospinning was set to a voltage of 80 kV and a frequency shift of the carrier fabric (spunbond) 5 Hz and 10 Hz and a rotating cylindrical electrode was used. The electrode was 500 mm wide, determining the width of the produced textiles. Nanofiber textile was then stabilized in an oven at 140°C for 10 minutes and then the 50 mm wide margins were cut off on both sides because of their poor quality.

From the produced textiles there were prepared rectangular samples having the dimensions of 130 mm × 25 mm. These samples were strengthened at both ends by a paper tape in order to avoid damaging of the sample edges before and during the tensile testing. The polymeric support textile (spunbond) had to be also removed from the samples in order to eliminate its influence on the experiment.

The testing was performed on various samples, which differed by their weights per square meter. The average values within each set were: 4.8 g/m^2, 3.1 g/m^2, 1.4 g/m^2 and 0.7 g/m^2 for the reference PVA samples, while those textiles containing copper ions were produced in the weight 2.5 g/m^2 and 3.4 g/m^2.

The tensile strength testing was carried out on using the LabTest 4.100SP1 device. The measuring range was set to 50 N maximum where the accuracy exceeds 0.1 % (at the magnitude of 2 N). The procedure was similar to the testing of macroscopic conventional samples, but the manipulation was rather complicated due to the very limited weight of the nanofiber textiles. Too low weight of the sample would result in a very fragile structure and the spunbond removal and fixation into the device's jaws would be impossible [10]. Fig. 1 shows the arrangement of the measurement and failure of a textile in tension.

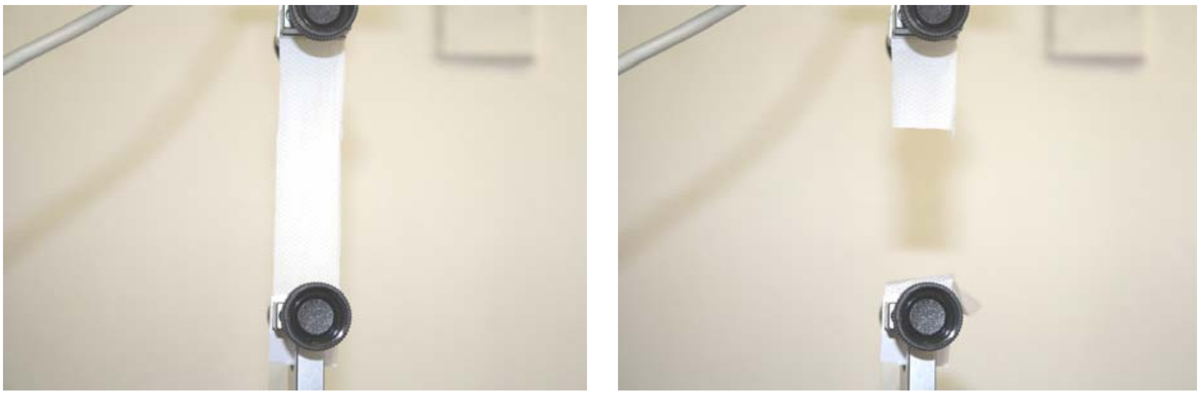

Fig. 1: Arrangement of the measurement; sample during loading (left) and sample after failure (right)

Results and discussion

The samples were tested in order to find their stiffness and tensile strength, and the influence of the copper ions on the PVA-based nanofiber textiles was investigated. Figs 2, 3 and 4 show the dependence of the mechanical properties of PVA-based nanofiber textiles on their weight per unit area. It can be clearly seen from the fitting curve, that the relationship between strength and stiffness, and the nanotextile weight is linear. The linearity is valid even if the textile is composed of more layers, indicating that the bond between the layers is perfect and no slip occurs.

The measured force-displacement diagrams for textiles containing copper are depicted in Fig. 3. It is obvious that the textiles containing copper exhibit higher stiffness and tensile strength, as well as their ductility, compared to plain PVA-based sample.

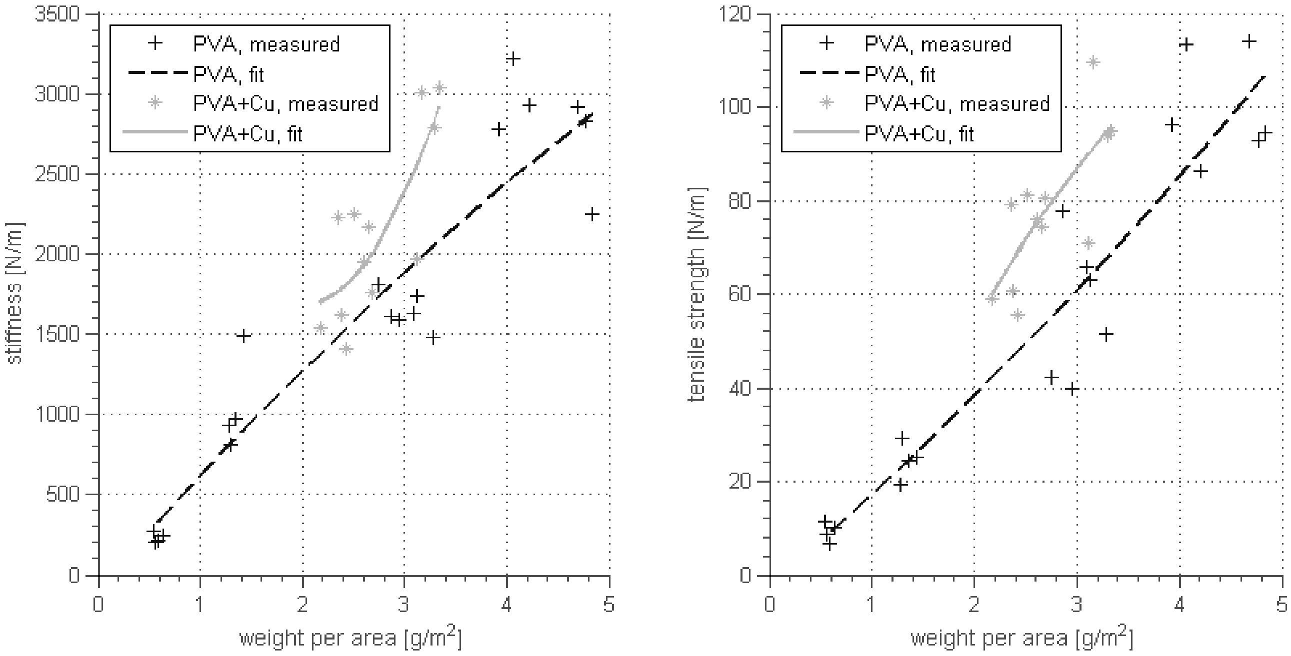

Fig. 2: Dependence of nanofiber textile stiffness (left) and tensile strength (right) on its weight per unit area

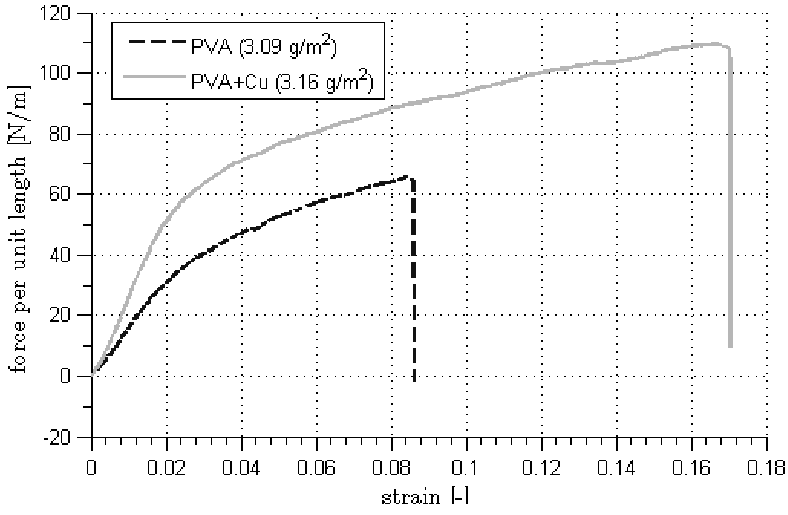

Fig. 3: Comparison of the typical force-strain diagrams of plain PVA-based nanofiber textile (PVA) and PVA based nanofiber textile with incorporated copper ions (PVA+Cu)

Summary

The results of our study show the influence of addition of metal ions, in particular copper ions, on the mechanical properties of nanofiber textiles. This type of textile can be utilized for its antimicrobial characteristics due to presence of copper. The results clearly indicate that the copper ions contribute to an enhancement of the tensile strength and stiffness of the PVA-based nanofiber textiles.

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