SECTION 1. INDUSTRIAL TECHNOLOGIES AND EQUIPMENT

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ASSESSMENT OF ADHESION OF NANOFIBER MATERIALS

ОЦЕНКА АДГЕЗИИ НАНОВОЛОКНИСТЫХ МАТЕРИАЛОВ

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Abstract. The work is devoted to assessing the adhesion of electrospun nanofiber materials to various types of substrates. A test procedure for determining the adhesion strength of nanofibrous materials based on a Time WDW tensile testing machine is described. A technique has been developed to reliably estimate the average value of the peel-off force of electrospun materials.
Аннотация. Работа посвящена оценке адгезии нановолокнистых электроформованных материалов к различным видам подложек. Описана методика проведения испытаний по определению адгезионной прочности нановолокнистых материалов на базе разрывной машины серии Time WDW. Разработана методика, позволяющая наиболее достоверно оценить среднее значение силы отслаивания электроформованных материалов.

Currently, one of the most promising areas for the development of innovative materials for biomedicine and cosmetology is the creation of electrospun materials. Due to the variety of their properties, they have become alternative therapeutic agents for many areas of biomedicine [1, 2, 3]. Such innovative materials [4, 5] can be produced for use on a substrate or require removal from it before use, which makes it relevant to study the adhesion of electrospun webs to various types of substrates.

We reviewed the studies devoted to methods for determining the adhesion strength of various materials and found that currently there is no method for assessing adhesion for electrospun polymer webs. In this regard, we proposed criteria for assessing adhesion: the peel-off force of removing nanofibrous web from the substrate, the absence of a large proportion of nanofibers migrating to the substrate or damage of the material [6]. On the basis of a Time WDW tensile testing machine designed for static tensile, compression and bending tests, a method for determining the adhesion of a nanofiber coating to a substrate has been developed.

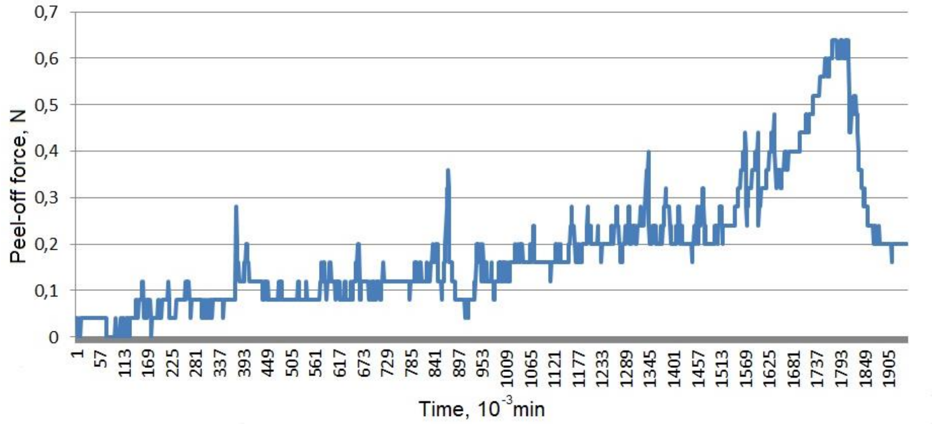
The pulling bottom clamp holds a horizontal plate to which the test specimen substrate is fixed. One end of the nanofiber material is fixed in the top clamp. The clamp is connected to the force transducer, the fluctuation of the force value is displayed by the oscillogram. The tensile machine helps to adjust the peeling speed of the material, as well as the clamping length.

Two samples of materials with nanofiber coatings were selected as objects of research [7]. The concentration of polyvinyl alcohol Arkofil PPL (Switzerland) in the fiber-forming solution was 14 %, the sample time was 30 min, tip-to-collector distance was 10 cm, the voltage applied to the emitter was 29 kV, to the collector – 9 kV, the polymer flow rate was 1.3 ml/h, the rotation speed of the collector – 250 min^{-1}. For the first sample, paper with the layer of black ink applied on the printer was used as a substrate. A black polyester fabric was used as a substrate for the second sample. The choice of these substrate materials is due to the fact that they both have relatively weak adhesion to nanofiber materials made of polyvinyl alcohol; coating defects and its fragments remaining after removing the coating are clearly visible on a black background. The clamping length at the beginning of the test was 5 cm, the width of the tested samples was 10 cm. The peeling process took place at a speed of 50 mm/min and was uniform. Photos of the samples and the oscillograms corresponding to the process are shown in Figures 1 and 2, respectively.

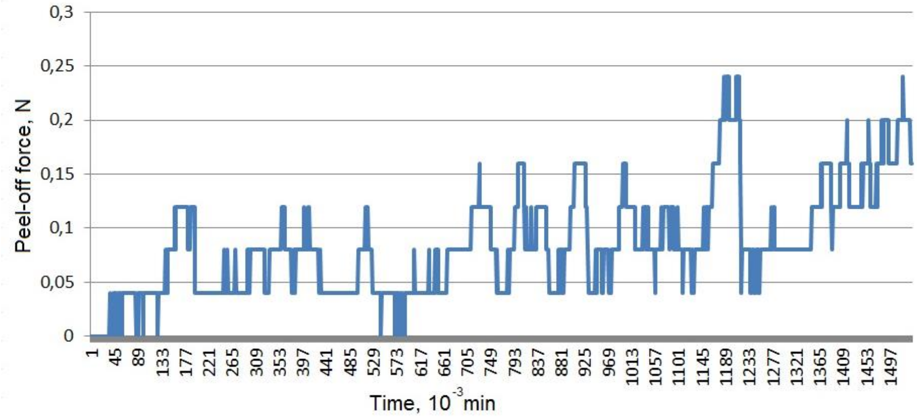

a)


b)

Figure 1 – Removal of nanofibrous material from: a) paper, b) fabric



a)



b)

Figure 2 – Oscillogram of peeling of nanofiber material from a) paper, b) fabric

Analysis of the results obtained showed that both samples peel off well from the substrate. We have developed a technique that allows us to reliably determine the average value of the peel-off force. For the evaluation, a segment was chosen at which a sample of nanofibrous material peels off at an angle of 90° +/- 5°, since in this case the deformation force acting on the material will be minimal and can be neglected. The peel-off force of the nanofibrous material from the paper was 9.9 cN, while for the sample of nanofiber webs on the polyester fabric it was 15.3 cN. One of the drawbacks of the sample accumulated on paper was the partial migration of nanofibers onto the substrate and particles of the substrate onto the nanofiber material during its peeling off the substrate. At the same time, for the sample, for which a polyester fabric was used as a substrate, such a defect is absent. However, the sample on the fabric is characterized by less uniformity of the nanofiber web, which in the future may adversely affect its operational properties.

Thus, if its uniformity is important for the further use of a nanofiber material, it is advisable to use paper as a substrate in its production, since it not only produces a more uniform coating, but also can be removed with a uniform force. However, if the material is supposed to be used in biomedicine and cosmetology, where it is important to ensure that there is no migration of nanofibers to the substrate and the particles of the substrate to the resulting material, it is advisable to use materials obtained on fabric, because there such migration tends to zero.

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