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Research of viscoelastic and hygroscopic properties of adhesive, textile materials and packages based on them

Natalia Bereznenko[1], Larysa Bilotska[2], Halina Szafrańska[3,*]

[1]*Taras Shevchenko National University of Kyiv, Kyiv, Ukraine*
[2]*Kyiv National University of Technologies and Design, Kyiv, Ukraine*
[3]*Casimir Pulaski Radom University, Radom, Poland*
*Corresponding author *h.szafranska@uthrad.pl,*

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ABSTRACT

Materials with multifunctional properties are the future of modern clothing, and the creation of such materials is extremely urgent. When creating such materials, it is appropriate to use non-woven nano-modified materials as components of clothing details. At the same time, it is important to ensure the viscoelastic and hygroscopic properties of packages of materials for making clothes. This study presents the analysis of these important properties of tissue packages depending on the parameters of their duplication.

Keywords
nano-modified materials,
clothing details,
elastic constants,
textile materials

1 Introduction

Manufacturers of clothes pay great attention to the fabrics from which they are made. Not only the appearance and durability of the product depend on the quality of the material, but also how comfortable it is to wear it. Today, materials with unique characteristics are produced, such as lightness, elasticity, strength, non-shrinking, the ability to quickly evaporate moisture, etc. Such fabrics do not stick to the body, do not deteriorate under the influence of salt water and hold their shape very well, that is, they do not change their linear dimensions after wet contact.

To ensure the multi-functionality of the products during their manufacture, fabric packages are used, which ultimately make it possible to ensure full comfort during the use of the products.

So, materials with multifunctional properties are the future of modern clothing, and therefore the search for opportunities to create materials with multifunctional properties is extremely relevant. In this regard, the use of non-woven nano-modified materials as components of clothing parts can be distinguished as the task of ensuring viscoelastic and hygroscopic properties of packages of materials for the manufacture of clothing.

The most important characteristics that determine the operational properties of textile materials are elastic constants. Determining the elastic constants of textile materials is easier and more accurate by using dynamic methods, taking into account their specific features, namely their small thickness [1-3]. As evidenced by the research results [4,5], by combining the mutual orientation of the axes of viscoelasticity of package elements it is possible to variably solve the issue of the formation of configurations of viscoelasticity fields due to the transformation of an anisotropic structure into an orthotropic one.

Analysis of literature data showed [6,7] that there are grapho-analytical methods and models of duplicating technological processes to ensure dimensional stability of clothing parts using structural, mechanical and rheological characteristics, in particular of linen fabrics and packages based on them. This allows you to predict the quality of the adhesive joint and determine the rational parameters of duplicating linen-containing fabrics depending on the type of duplicating equipment, duplicating modes, structural features of upper fabrics and lining materials.

There is also experience [8,9] of using methods of visualization spectroscopy and controlled pattern recognition to determine the viscoelastic properties of cotton fabrics, in particular bed linen and towels. In the course of the conducted research, a change in the viscosity of cotton was detected on the image spectra, which were classified according to different viscosity ranges using discriminant analysis. It was determined that the viscoelastic characteristics of cotton fabrics depend on their moisture content.

Also known are the results of research [10-12] on providing dimensional stability to textile products, including clothes made of genuine leather, using the method of chemical modification and activation of its surface, which makes it possible to more effectively use various textile materials, in particular leather raw materials at the stage of cutting.

The methods of evaluation of textile materials involve the study of the interrelationship of their individual properties. The resources of periodicals present works devoted to the evaluation of dimensional stability from the standpoint of studying the properties of fabrics. In particular, the scientists proposed a comprehensive indicator of the dimensional stability of the fabric, which is based on the determination by the express method of a number of constituent characteristics: elasticity, immutability and tendency of the fabric to be compressed, as well as a method of assessing the relaxation properties of materials during bending of suit worsted and fabrics and their adhesive joints with hot-melt adhesives gasket materials [13,14].

The most important characteristics that determine the operational properties of textile materials and changes in their structure are elastic constants, among them the dynamic modulus of elasticity (Ed) and the damping decrement (δ). To implement an effective process of duplicating the created packages, it is necessary to analyze the above indicators in different directions (on the basis, on the weft and under 45°). The study of hygroscopic indicators of textile material packages makes it possible to predict the performance characteristics of clothing from the presented textile material packages.

The purpose of this study is a comprehensive investigation of the most effective arrangement of elements of the material package from the point of view of viscoelastic characteristics.

2 Materials and methods

In this study, the determination of the dynamic modulus of elasticity and the decrement of stiffness damping of adhesive, textile materials and packages based on them was carried out in the research laboratory of the Kyiv National University of Technology and Design at the UDM-1 installation (Fig. 1). The installation is designed to determine the stiffness of textile materials and packages based on them under temperature conditions. The attenuation decrement was determined by the width of the resonance trough of the amplitude curve of the exciting force at constant sample amplitude.

The modulus of elasticity was estimated by the ratio of the stress that develops in the material to the relative deformation of the material.

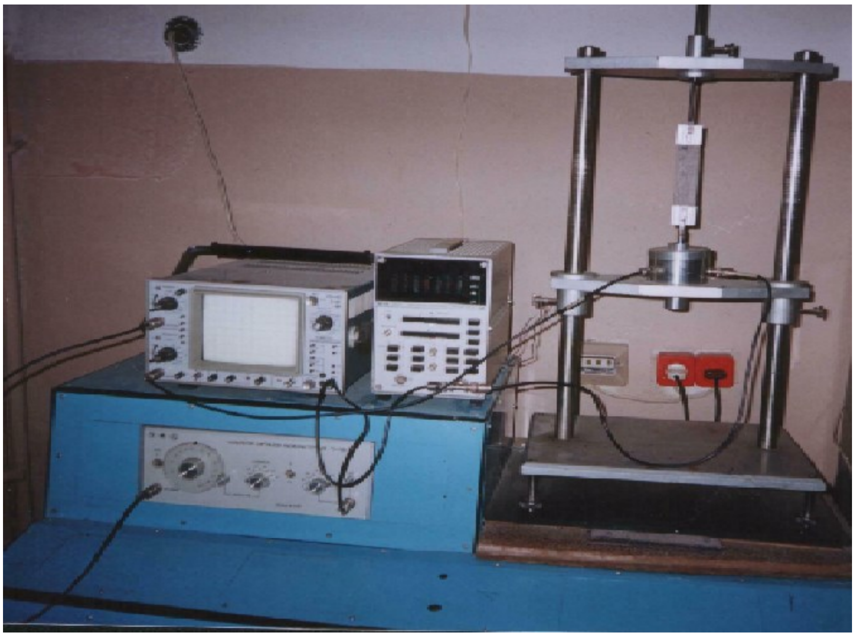


Fig. 1 Installation for determining the dynamic properties of materials.

The original materials for determining rational duplicating parameters for the creation of packages with nano-modified elements are:

1- adhesive threads based on low-melting polyethylene,
2- non-woven material, in which 70% are natural fibers (hemp), 30% are synthetic (polypropylene, polyester, including 15% low-melting components (polyethylene, polyester) and
3- upper material (suit fabric) (Fig. 2).

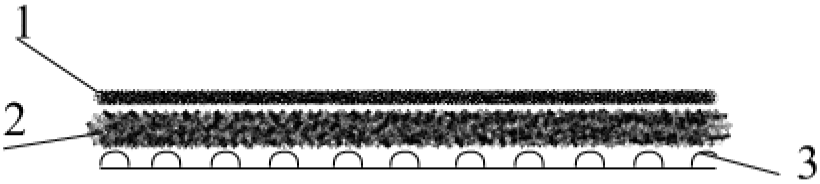


Fig. 2 Package with the content of nano-modified components in cross-section, 1 – non-woven material, 2 – low-melting components (polyethylene, polyester), 3 – upper material (suit fabric).

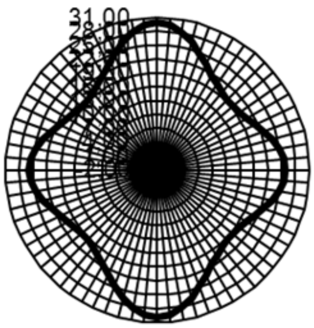
3 Results and discussion

From the practice of researching the properties of textile and leather materials, it is known that they have different viscoelastic properties in the longitudinal, transverse direction and at an angle of 45°. Therefore, studies of dynamic modulus of elasticity (Ed) and damping decrement (δ) for created packages in different directions were conducted (Fig. 3-7, Table 1).

Determination of dynamic properties of materials was carried out at the UDM1 installation. In each of the variants of research, three elementary samples were used, which makes it possible to obtain more accurate values of the indicators Ed and δ.

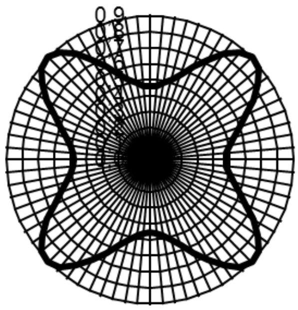
The results of the research (Fig. 3-7, Table 1) reveal a clearly expressed longitudinal nature of viscoelastic properties in those samples that were duplicated at Tv.p = 140 °C, Tv.p = 150 °C, Tv.p = 160 °C and t = 15 s (const), while in samples that were duplicated at Tv,p = 150 °C (const), and duplication time t = 10 s, t = 15 s, t = 20 s, more pronounced longitudinal and transverse viscoelastic properties, as evidenced by the values of the δ indicators.

a



Ed

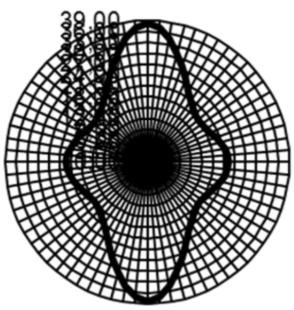
b



δ

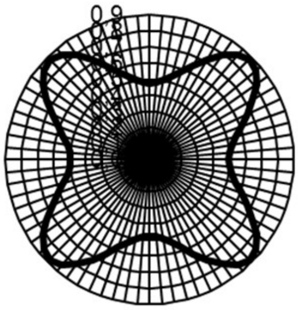
Fig. 3 Diagrams of indicators of (a) the modulus of elasticity Ed (MPa) and (b) the attenuation decrement δ of the original materials with the duplication parameters Tv.p = 150 °C, Tn.p = 100 °C, t = 10 s (Tv.p and Tn.p – temperature of the upper and lower pads of the press).

a



Ed

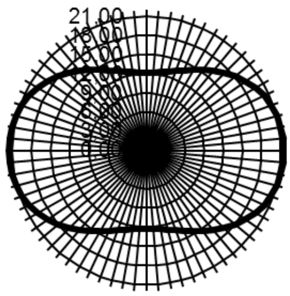
b



δ

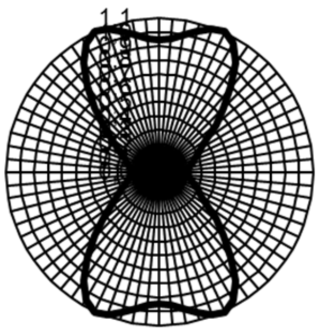
Fig. 4 Diagrams of indicators of (a) the modulus of elasticity Ed (MPa) and (b) the attenuation decrement δ of the original materials with duplication parameters Tv.p = 150 °C, Tn.p = 100 °C, t = 15 s.

a



Ed

b



δ

Fig. 5 Diagrams of indicators of (a) the modulus of elasticity Ed (MPa) and (b) the attenuation decrement δ of the original materials with duplication parameters Tv.p = 150 °C, Tn.p = 100 °C, t = 20 s.

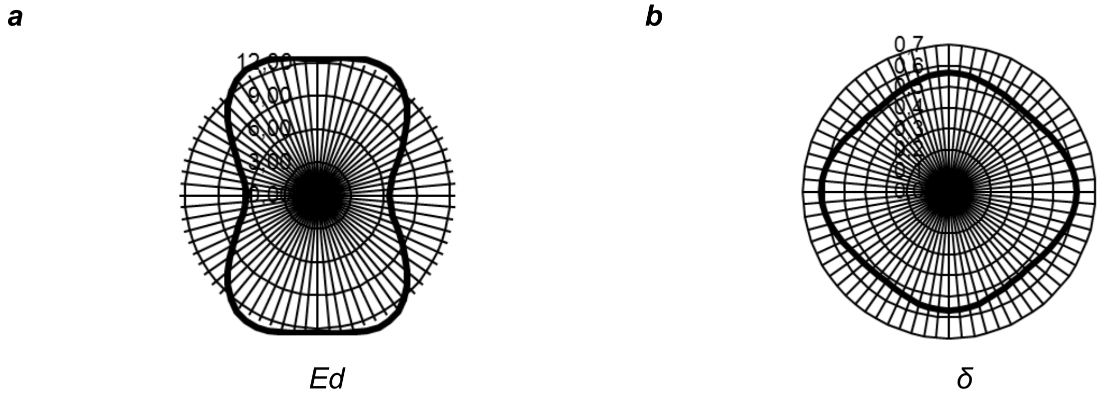


Fig. 6 Diagrams of indicators of (a) the modulus of elasticity Ed (MPa) and (b) the attenuation decrement δ of the original materials with duplication parameters Tv.p = 140 °C, Tn.p = 100 °C, t = 15 s.

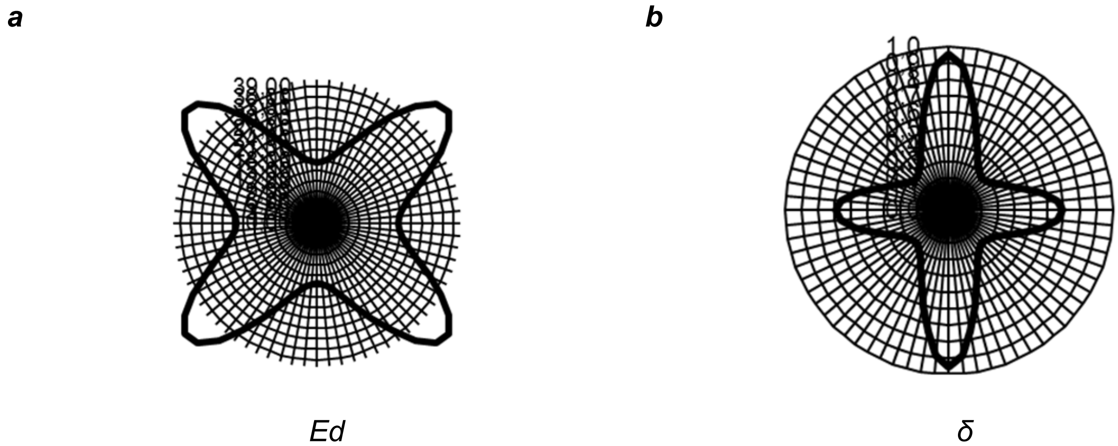


Fig. 7 Diagrams of indicators of (a) the modulus of elasticity Ed (MPa) and (b) the attenuation decrement δ of the original materials with duplication parameters Tv.p = 160 °C, Tn.p = 100 °C, t = 15 s.

Table 1. Results of studies of the dynamic modulus of elasticity and decrement of damping of the package

Package duplication options	Research direction	Dynamic characteristics	
		Ed (MPa)	δ
Tv.p = 150 °C, Tn.p = 100 °C, t = 10 s	Along the basis	30.0113	0.4576
	At an angle of 45°	19.4851	0.9077
	Along the weft	25.8894	0.4766
Tv.p = 150 °C, Tn.p = 100 °C, t = 15 s	Along the basis	38.3100	0.4746
	At an angle of 45°	18.6266	0.8803
	Along the weft	22.2929	0.4952
Tv.p = 150 °C, Tn.p = 100 °C, t = 20 s	Along the basis	12.2068	0.9455
	At an angle of 45°	17.1660	0.6520
	Along the weft	21.4939	0.2069
Tv.p = 140 °C, Tn.p = 100 °C, t = 15 s	Along the basis	12.4067	0.5675
	At an angle of 45°	11.4503	0.5250
	Along the weft	6.5132	0.6114
Tv.p = 160 °C, Tn.p = 100 °C, t = 15 s	Along the basis	17.2747	0.9537
	At an angle of 45°	48.3030	0.2718
	Along the weft	23.1352	0.6938

This can be explained by the unstable, mobile structure of the package, which is caused by the use of non-woven material based on hemp fibers (70% hemp fibers, 15%, PE, 15% low-melting PE) in the package. It should be noted a sharp change in viscoelastic properties in the package, which is duplicated at Tv.p = 150 °C, Tn.p = 100 °C, t = 20 s and Tv.n = 160 °C, Tn.p = 100 °C, t = 15 s. This is explained by the transition of the non-woven material (100% polypropylene) into a viscous-fluid state in both the first and second cases. Therefore, the following duplicating parameters can be considered rational: Tv.p = 150 °C, t = 15 s.

A study of the hygroscopicity of the package was also conducted, since this indicator has an important hygienic value (Table 2). All fabrics, except for synthetic fabrics, have high hygroscopicity, that is, the ability to absorb moisture from the environment and release it.

Table 2. Hygroscopicity of the investigated packages and original materials

Package composition	Package number	Package duplication options	Hygroscopicity (%) 4 hours	Hygroscopicity (%) 12 hours
Adhesive material, 100% polyester	1	–	–	4.3
PP-based non-woven material	2	–	4.0	–
Non-woven material, 70% hemp fibers, 15% PP, 15% low-melting components	3	–	10.9	20.8
Non-woven material, 70% hemp fibers, 15% PP, 15% low-melting components	4A	Tv.p = 150 °C, Tn.p = 100 °C, t = 10 s	4.4	9.9
	4B	Tv.p = 150 °C, Tn.p = 100 °C, t = 15 s	5.8	11.5
	4C	Tv.p = 150 °C, Tn.p = 100 °C, t = 20 s	6.7	13.9
	4D	Tv.p = 140 °C, Tn.p = 100 °C, t = 15 s	5.6	6.7
	4E	Tv.p = 150 °C, Tn.p = 100 °C, t = 15 s	5.8	6.8
	4F	Tv.p = 160 °C, Tn.p = 100 °C, t = 15 s	5.2	6.9

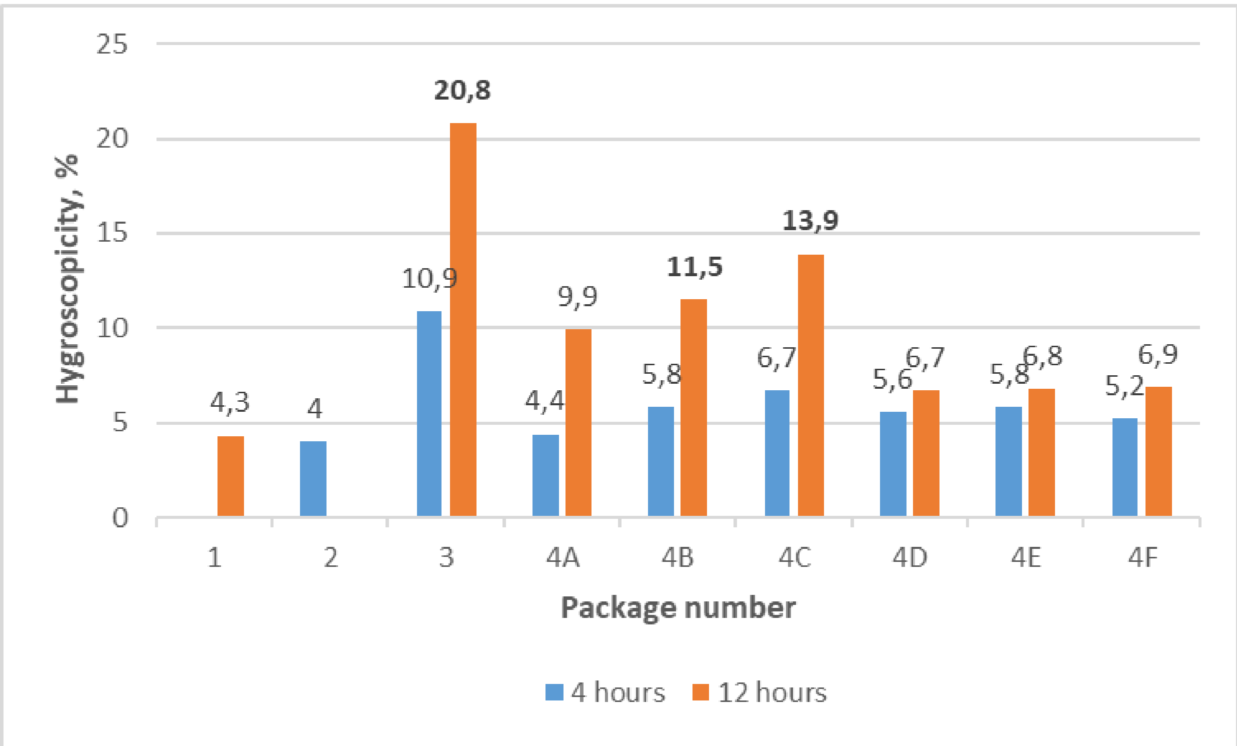


Fig. 8 Hygroscopicity diagram of the tested packaging and original materials

This ability of fabrics is very important in hot weather, when the human body temperature rises. The hygroscopicity of textile products depends on the type of fibers from which they are made, on the fabric structures and the nature of the final treatment. Determination of hygroscopicity was carried out in accordance with DSTU GOST 3816 – 81 (ISO 811-81) for packages (package containing costume fabric, non-woven material based on hemp fibers (70% hemp fibers, 15 PE, 15% low-melting substances) and adhesive material) created with different duplicating parameters. Table 2 and Fig. 8 show that non-woven material based on hemp fibers has a high degree of hygroscopicity, namely 20.8%. As for the indicators of the created packages, depending on the duplication parameters and the research time, they can change the range of values. The hygroscopicity of the packages increases with increasing duplicating time and sharply decreases (research time – 4 hours) at duplicating parameters Tv.p = 160 °C, Tn,p = 100 °C, t = 15 s. This is explained by the fact that at Tv.p = 160 °C, the non-woven material with the given duplicating parameters goes into a viscous-fluid state and thus creates a barrier for moisture diffusion. As the data show, the package with duplication parameters Tv,p = 150 °C (const), t = 15 s has the best hygroscopic properties.

4 Conclusions and outlook

Due to the revealed peculiarities of the formation of stiffness and elasticity fields, the possibility of using different schemes of mutual arrangement of the axes of elastic symmetry of monolayers for duplicating individual parts of the products is substantiated. It was determined that the stiffness of the package depends on the duplicating temperature and duplicating time.

The following duplicating parameters can be considered rational: Tv.p = 150 °C, t = 15 s. In addition, the stiffness of the packages is significantly affected by the spatial arrangement of the threads of the adhesive material. It was established that the most effective, from the point of view of viscoelastic characteristics, is the option of mutually perpendicular arrangement of material elements.

Research of viscoelastic properties and damping decrement showed both transverse and longitudinal nature of changes in viscoelastic properties. This can be explained by such a factor as the uneven location of the non-woven material along the entire length of the sample.

The greatest hygroscopicity of packages is ensured at the duplication parameters Tv.p = 150 °C, t = 15 s.

Author Contributions

N. Bereznenko, L. Bilotska: conceptualization, methodology, investigation, visualization, writing – original draft preparation; H. Szafrańska: supervision, writing – original draft preparation.

Conflicts of Interest

The authors declare no conflict of interest.

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