TWO-DIMENSIONAL STUDIES OF THERMOMECHANICAL PROPERTIES OF TEXTILE MATERIALS FOR 3D FORMATION

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Abstract: *The article defines the parameters of forming and form resistance of textile materials taking into account the properties of anisotropy on the basis of constructing a model of thermomechanical deformation of textile material, experimental research on three-dimensional deformation. The model of two-dimensional thermomechanical deformation is presented. Correlation dependencies between parameters of thermomechanical deformation and structural characteristics of a material are determined.*

Keywords: *uniformity, form formation, thermomechanical characteristics, structural parameters, two-dimensional tests, three-dimensional deformation.*

1 INTRODUCTION

The ability of textile materials to form is a very important property that determines the choice of an optimal method for obtaining the silhouette of garments and affects their quality. The required form for product parts is provided by means of wet-heat treatment, which is a very important part of the technological process of making clothes. Formation of new materials in wet-heat treatment is not sufficiently studied, which makes it difficult to manufacture products from them. As the assortment of new materials is constantly updated, there is a problem of constant experimental research of their formation in the wet-heat treatment. In connection with this study of the formation of textile materials is an urgent task.

The real form of a textile product has a pronounced three-dimensional character. At the same time, the process of wet-heat treatment involves changing the shape and size of textile materials having different thermomechanical properties in different directions. It should be noted that modern processes of wet-heat treatment of textile materials are insufficiently provided with scientifically grounded regimes. In studies conducted on the determination of the properties of textile materials, as a rule, their anisotropy is not taken into account.

Problems of the formation of textile materials for light industry, in particular by means of thermomechanical transformations, are considered in a number of papers [1-2]. The application of theories of deforming textile materials under the action of heat and load was carried out in [3], in particular, the heat transfer theories for the design of processes was taken into account, although real regimes were not considered.

Attempts for mathematical modeling of deformation processes of textile materials are periodically carried out, although their practical application is difficult to implement. For example, in [4], a method for solving this problem by employing finite element (FE) techniques in two scales was presented, using the results of analysis at the meso scale (the scale of the repeating unit) to provide an equivalent non-linear spring behavior for each textile link at the macro-scale. It should be determined that finite-element is a very powerful method but not always adapted to reality. In addition, it requires the definition of real mechanical and thermal characteristics.

Attempts to simulate the thermomechanical characteristics for the purpose of designing deformation processes were also made in [5]. The main thermomechanical effects arising in textile materials are discussed in [6], the effects of the influence of force and temperature - in [7], especially the materials for the production of clothing - in [8].

Experimental studies that determine the properties of textile materials in two directions were carried out in works [9-10], although the model of double-sided deformation was not built. Multifunctional modeling of the processes of the thermoelastic behavior was carried out in [11], although the results are difficult to distribute to real textile materials.

The purpose of this work is to determine the parameters of shaping and shape resistance of textile materials taking into account the properties of anisotropy on the basis of constructing a model of thermomechanical deformation of textile material, experimental studies on three-dimensional deformation.

2 EXPERIMENTAL PART

As already mentioned, the real modes of deformation of materials are at least two-dimensional in nature. It is also necessary to take into account the real properties of polymers, which also include textile materials. The most characteristic feature is anisotropy - different properties of materials in different directions. These properties must be taken into account when designing the technological processes of changing the shape.

Unfortunately, data on two-dimensional deformation of materials is practically absent. We have developed the experimental device, then worked out technique and obtained the results in a two-dimensional test of polymer materials (Figure 1). During realization of this experiment, the sample is loaded in two perpendicular directions. At the same time it was heated. Changes in size were fixed in two directions.

The group of dependences of the longitudinal and transverse deformation of the material were constructed by changing the ratio of longitudinal and transverse forces.

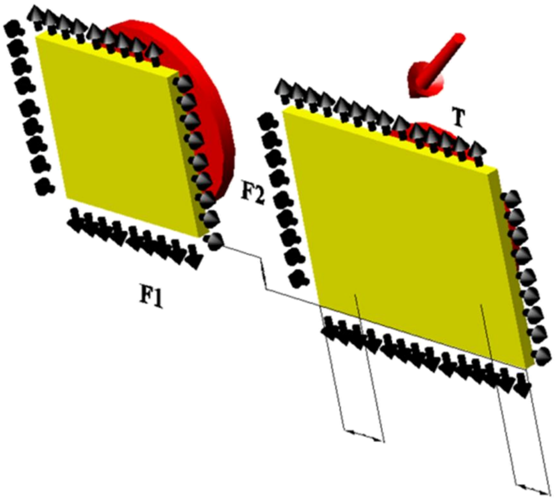

Figure 1 Definition of two-dimensional thermomechanical characteristics

As a result of the obtained studies a complex of dependencies is suggested, which for a particular material can be written as a system:

$$\begin{cases} \varepsilon_1 = f_{11}(t)\cdot\sigma_1 - f_{12}(t)\cdot\sigma_2 \\ \varepsilon_2 = -f_{21}(t)\cdot\sigma_1 + f_{22}(t)\cdot\sigma_2 \end{cases} \qquad (1)$$

where ε_1, ε_2 - relative deformations in two directions, σ_1, σ_2 - mechanical stresses in these directions, f_{ij} - thermomechanical characteristics of stiffness, found from the experiments.

Let's write down the voltage through the deformation. We'll get it.

$$\begin{cases} \sigma_2\left(f_{22} - \dfrac{f_{12}\cdot f_{21}}{f_{11}}\right) = \varepsilon_2 + \dfrac{f_{21}}{f_{11}}\cdot\varepsilon_1 \\ \sigma_1\left(f_{11} - \dfrac{f_{12}\cdot f_{21}}{f_{22}}\right) = \varepsilon_1 + \dfrac{f_{12}}{f_{22}}\cdot\varepsilon_2 \end{cases} \qquad (2)$$

In the case of known values of deformations from the system, we can obtain the values of stresses that determine the external loads on the material, as well as the necessary temperature distribution on the material surface to provide the given deformations (Figure 2).

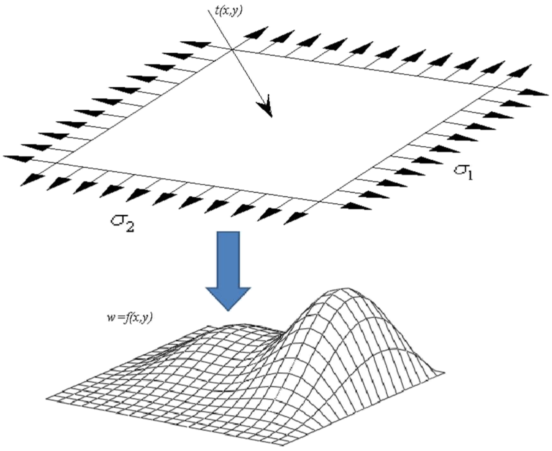

Figure 2 Thermomechanical deformation of textile material

Thus it is possible to solve the problem of creating a convex form of the surface of a textile material by its stretching with simultaneous heating. In the future, we will call the shaping the value of the convexity. The convexity of the material that occurs when heated with the simultaneous loading of the textile material determines its shaping.

The study of the formation of textile materials was carried out on an experimental device, which is depicted in Figure 3.

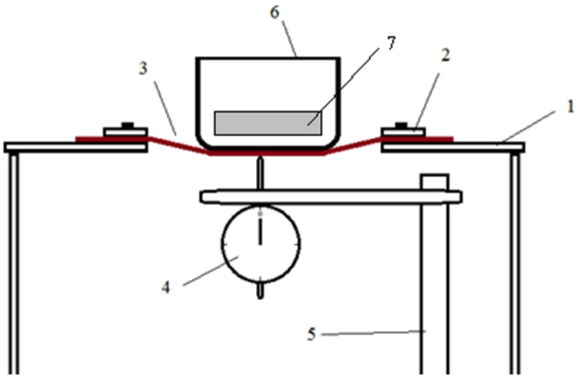

Figure 3 The scheme of measurement of formation during heating; 1 - the platform, 2 - clamp of the fabric, 3 - sample of the investigated fabric, 4 - indicator of movement, 5 - tripod of indicator, 6 - capacity with electric heater

The device is imagines, from from your point of view, as a platform with a round hole and a special clamp to hold the fabric. On a stretched fabric was a container with a convex surface, inside which was an electric heater. The temperature of the fabric was measured at regular intervals using the infrared thermometer MS6530.

Ten samples of tissues have been selected and studied for research. These fabrics are characterized by surface density, a kind of weaving and fibrous composition. For the experiment, blended fabrics containing wool with polyester fibers were selected in different ratios.

3 RESULTS AND DISSCUSSION

Figures 4-6 show the results for fabrics with different content of polyester fibers. For the experiments, fabrics with a content of polyester fibers of 18, 22, 34, 48, 56, 67, 74, 87 percent were chosen, designated respectively T9, T8, T7, T6, T5, T4, T3, T2, T1.

Dependence of temperature *T* [ºC] on the time *t* [s×10²] for the investigated fabrics is presented in Figure 4. The temperature range of the measurement were changed from 20 to 210°C.

The graph shows that the heating rate of the samples was approximately the same, which indicates the same conditions for conducting experiments. The temperature of the fabrics for all samples initially rose intensively, then the rate of lifting slowed down and then practically did not change.

The dependence of shaping *F* [%] of time *t* [s×10²] for the investigated tissues is presented in Figure 5.

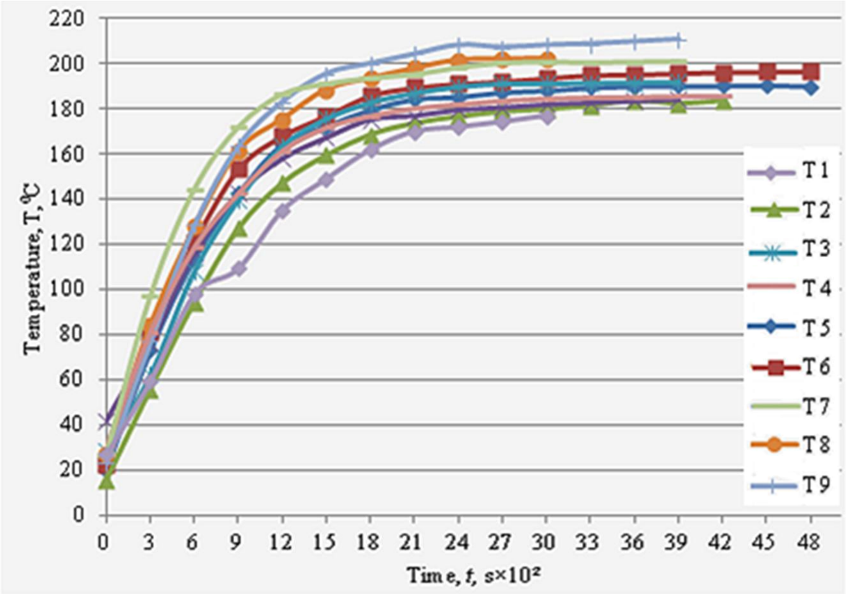

Figure 4 Dependence of temperature on time for investigated fabrics

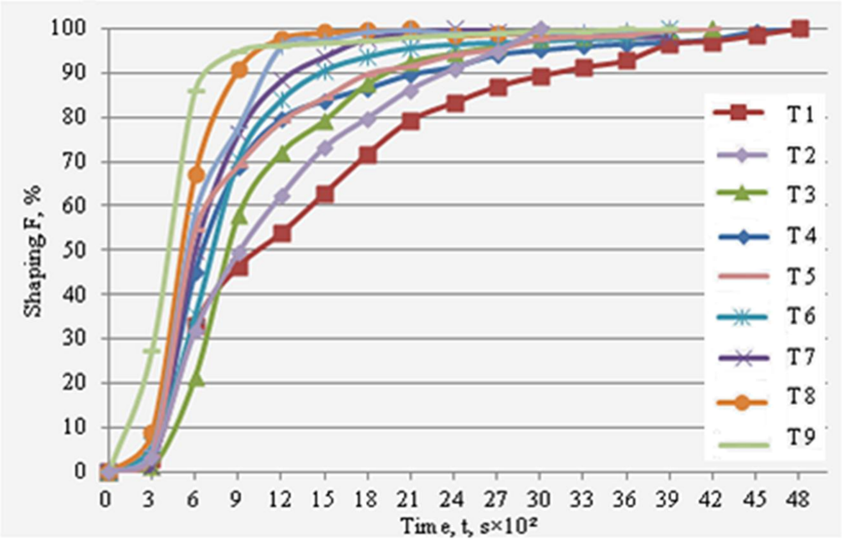

Figure 5 The dependence of shaping on time for investigated fabrics

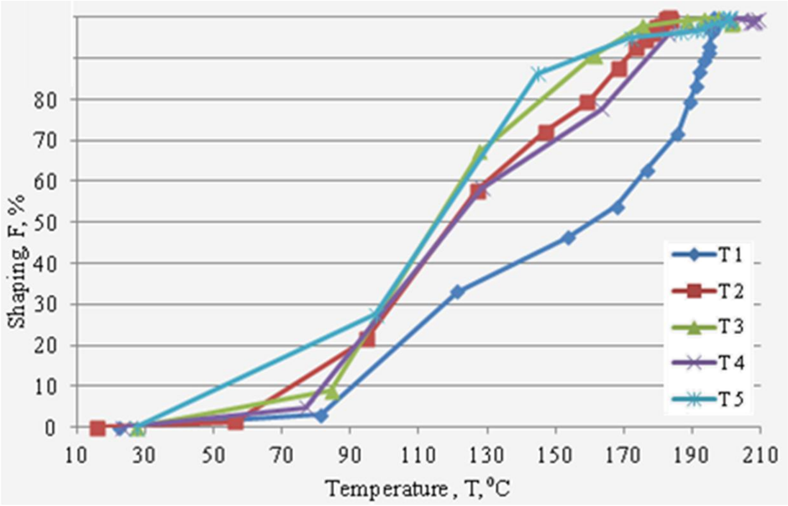

Figure 6 Dependence of shaping on temperature for selected fabrics

As it follows from the graph for all samples before 300 second, the formulation increased very rapidly, and then slowed down. In the sample number 9, the formation became the fastest, and for the sample number 2, the slowest.

Dependence of shaping *F* [%] on temperature *T* [°C] for the group of samples is presented in Figure 6.

In all samples the formation began to increase strongly at a temperature of 55-95°C, the fastest formation took place at temperatures 170-190°C.A sufficiently high correlation is observed for the correlation coefficients between shaping and linear filling (Figure 7).

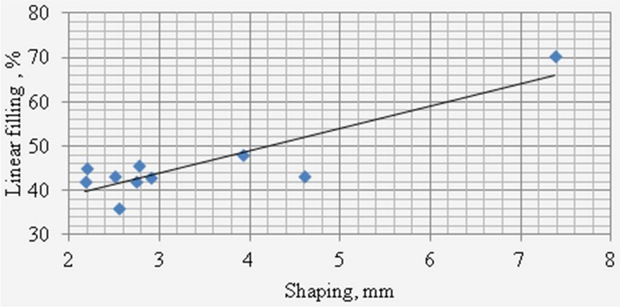

Figure 7 Correlation between shaping and linear filling

Also, the correlation of the rather high level is observed between the formation and the coefficient of connectivity. The correlation coefficient reaches R = 0.71, the correlation is high.

Thus, the magnitude of linear filling by weft unambiguously increases the possibility of shaping a textile material, with the magnitude of the maximum deformation approximately proportional to the magnitude of linear filling. The magnitude of the coupling coefficient unambiguously reduces the ability to shaping, while the reduction of the size of the formation is roughly proportional to the value of the coupling coefficient.

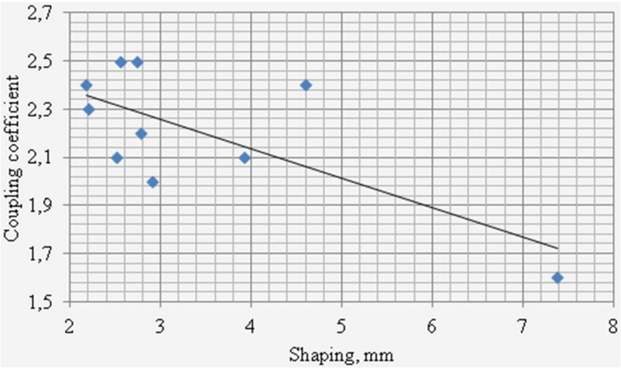

Figure 8 Correlation between shaping and coupling coefficient

After cooling the samples, measure the depth of formation. The measuring device is aligned so that the zero was at the level of the clamper fabric on the table of the installation.

Form resistance will be called the final deformation that remains in the textile material after cooling.

It was determined the influence of various factors on the form of resistance and correlation between them, in particular:

- deformation of the sample after cooling and deformation of the sample after ironing; uniformity and surface density; shape resistance and tendency to crunching, shape resistance and tendency to trickle down the duct; uniformity and draping properties; discontinuous efforts to form and break away after forming; relative elongation to formation and relative elongation after formation.

At the same time, the maximum influence on the value of the shape resistance gives the values of linear density and thickness of the threads (Figures 10 and 11). It was also determined the correlation between the discontinuous effort and the formation of the bursting forces after the formation, which is presented in Figure 9.

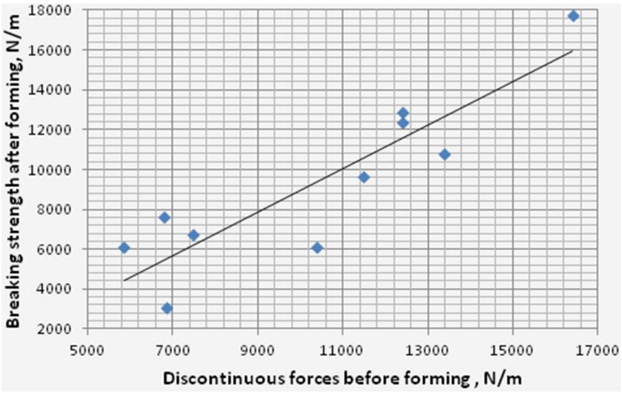

Figure 9 Correlation between discontinuous forces before forming and breaking strength after forming a weft

A high correlation is observed between the discontinuous forces before forming and the bursting forces after the formation of a weft, because R = 0.88. One can conclude that the effect of forming on the bursting force on the thread of weft is greater than the base thread.

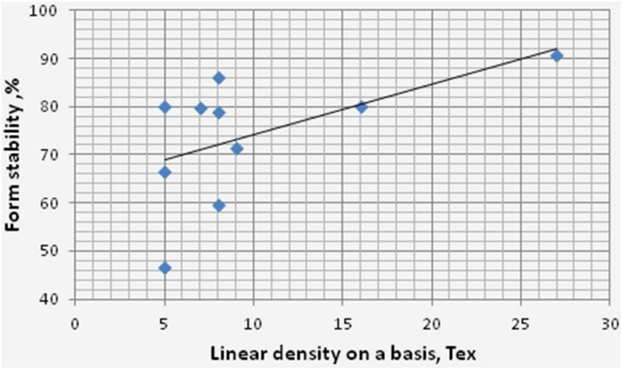

Figure 10 Correlation between form stability and linear density

There is the average correlation between the uniformity of form and the linear density, because R = 0.8. One can conclude that the greater the linear density on the basis, the better the shape resistance.

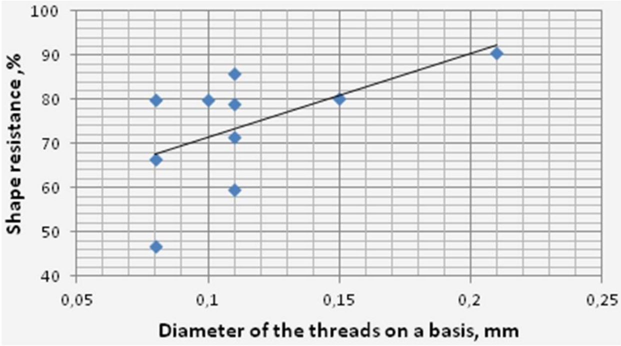

Figure 11 Correlation between the shape resistance and the diameter of the threads

There is the average correlation between the uniformity of the form and the diameter of the threads on based, because R = 0.78, which means that the larger the diameter of the threads on the basis, the better the shape resistance.

4 CONCLUSION

The conducted studies have proved the validity of two-dimensional thermomechanical characteristics of textile materials for the design of wet heat treatment processes.

The main indicators of the process of wet heat treatment of textile materials, shaping and shape resistance are functions of structural characteristics of materials.

The linear filling of the textile material uniquely increases the possibility of shaping the textile material, with the magnitude of the maximum deformation roughly proportional to the linear filling value. The value of the coupling coefficient unambiguously reduces the ability for shaping, while the reduction of the size of the formation is approximately proportional to the value of the coefficient of connectivity

Structural characteristics of materials also affect the shape resistance of textile materials. According to the research carried out, the structural integrity of the materials under investigation is mainly influenced by the linear density, the diameter of the filaments and the linear filling.

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