Ilqar Saleh Recabov*
Mahammadali Nuraddin Nuriyev**

Azerbaijan State Economic University (UNEC), Faculty of Engineering, Department of Engineering and Applied Sciences,
Istiglaliyyat str. 6, Baku, Azerbaijan, AZ1001,
* e-mail: Ilqar67@mail.ru,
** e-mail: mehman62@mail.ru

Evaluation of Deformation Properties of Elastic Fibres in Threads

DOI: 10.5604/01.3001.0014.9293

Abstract
In the article, the change in the linear dimensions of tissues is analysed by the closure of the elastane threads in the tissue system under the influence of wet processing. It is found that standard techniques cover changes in linear dimensions only in the direction of the base and utka. However, for clothing design, it is necessary to know the change in linear dimensions in arbitrary directions. The empirical models used to calculate these dimensions do not have the required accuracy. The article proposes a model for calculating the change in linear dimensions in an arbitrary direction based on the analysis of the geometry of the fabric and describing the process of tissue shrinkage under the influence of wet processing, which allows to obtain results with sufficient accuracy.

Key words: *elastic fabrics, deformation of threads, complex properties, shrinkage of fabric, shrinkage anisotropy, size stability.*

Introduction

Due to the multifaceted areas of application of textile materials for household purposes, their structure and property requirements are dictated by consumers.

Engineering design of fabrics is based on the ratio of the parameters of their structure and physical and mechanical properties. In this case, it is urgent to take into account the designation of fabrics, the properties of the raw materials used, the feature of the technological process, and the formation of textile materials.

The analytical method of household fabric design is processed by local and external researchers. However, the solution to this problem encounters great difficulties. Thus, textile products differ from building materials with respect to stable shape and not having high relaxation properties. Currently, the problem of the engineer design of fabrics is actual. It should be a method for determining the optimal parameters of the yarn and the process of forming the fabric, providing the required physical and mechanical properties of the fabric.

All these define the urgency of using methods of thread deformation property assessment of elastic fabrics.

Modern state of the problem and processing literature information data

The characteristic feature of fabrics is their anisotropy, being the result of a different layout of structural elements and their orientation [1]. Studies based on anisotropy are devoted to the mechanical properties of materials and alloys (pressure-treated plastics, fibres, plastics, shells etc.) [2]. There have been attempts to reduce the anisotropic mechanical properties of chemical fibres. The structure of fibres differ greatlu and depends on a great number of factors [3]. Unfortunately, studies on the anisotropic problems of fabrics are very few [4], and there is no experimental information about elastic fabrics.

However, it is impossible not to mention a number of studies which were devoted to variations in the geometric dimensions of fabrics during tightening, evaluated by various methods, such as a one-way tension in different directions while adorning rotational surfaces, during the free fall of the fabric etc. The problems of modelling the deformation ability of the forceps of costume fabrics at different angles on a relacometer have been studied in research. During tests of samples at angles of ± 15°, ± 30°, ± 60° and ± 75°, different inclinations from the vertical were recorded [5]. Studies were devoted to variations in the geometric dimensions of fabrics during a single curcuit. The experiments were conducted on samples cut at an angle of 15°, 30°, 45°, 60° and 75° degrees relative to the beam thread.

The rough structure and cage shapes of textile materials have been studied by a number of researchers [6]. During a study of staple viscose fabrics, the experimental results obtained allowed to determine that as the tension of the tissues decreases, the stretching of fabrics on the threads of both systems also decreases. The elongation on the beam thread is significantly greater than that on the weft thread .This is explained by the great effect of the beam thread.

Assessment of the effect of density on types of wear has been undertaken in a number of studies [7, 8]. Tests of viscose fabrics showed that the parameters of the structure affect the course of reverse relaxation of forces (density, thickness of the threads, tissues).

Studies of cotton, wool and lavsan fabrics, canvas and braided weaves show that an increase in weft density leads to a change in the elastic characteristics of both weft and beam threads.

Similar results were obtained in studies with simple and derivative viscose fabrics being the object of research. Estimating the components of the deformation, it was obtained that the rotating part of deformation increases when the density

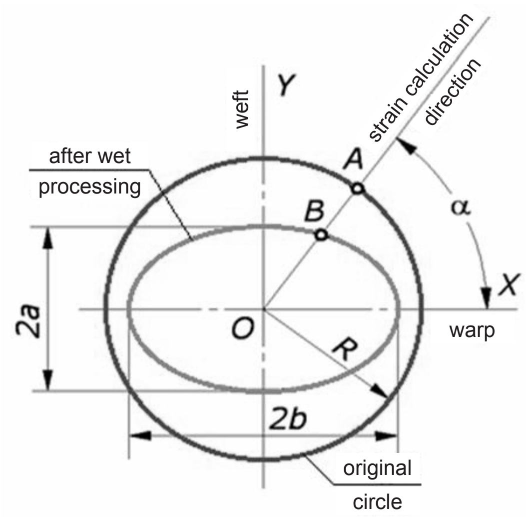

Figure 1. Deformation of fabric from the direction to beam thread.

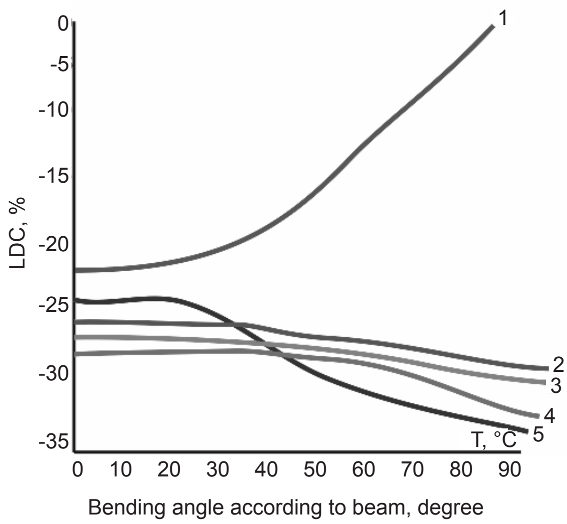

***Figure 2.** Comparative analysis of experimental results of linear dimension change, where: 1 – 0%, 2 – 7.0%, 3 – 2.61%, 4 – 1.61%, and 5 – 1.35% of elastane content.*

increases at small loads. Studies of the geometric dimensions of elastic fabrics made it possible to determine that the stretch ability of fabrics made from this type depends on the method of inserting the elastomer polyurethane thread on the canvas into the fabric and not on the main type of raw material.

Much work has been done to study the deformation properties of the ball. As the object of research, yarns with different raw materials: cotton, synthetic, mixed and viscose were taken. In this case, as test factors, the effect of time, loading speed and rest period on the cost of the load were evaluated. But very little work has been done on the effect of high elongation polyurethane fibres; however, this factor has a significant impact on the deformation properties of fabrics made of such fibres.

As the effect of wet and heat on the fabric decreases, the effect of intermolecular energy on the fibres decreases as well. Deformations during the wet and heat treatment of fibres cause a change in the molecular chains of fibre-forming polymers.

The reverse relaxation process is caused by the thermal oscillations of macromolecules and weakining of intermolecular bonds during hydration.

Thus, analysis of the methods for determining the change in the linear dimensions of fabrics showed that all available methods are designed for the study of traditional fabrics.

Purpose and task of the research

The main purpose of the work is to evaluate the deformation properties of threads in elastic fabrics.

The following tasks were set to achieve the goal:
- to predict changes in the deformation of threads in elastic fabrics and to specify the research method, as well as to quantify the anisotropy of the change in the size of the fabrics,
- to determine the extent of deformation of the threads in the fabrics in dependence on the type of yarn,
- to obtain the dependence of the anisotropy of the deformation change of fibres from the structure and the shrinkage limit of the fabrics after wet processing.

Results of analytical analysis to determine the deformation of fabric threads

It is sufficient to know the direction of the experimental value in order to determine the deformation in any direction passing through angle α in the direction of weft thread. For simple reporting in the future, let us assume the dimensions of deformation not in percentages but in parts from the initial dimensions. Thus,

$$\lambda = \frac{L_1 - L_0}{L_0} \quad (1)$$

Here L – length of the fabric after wet processing, L_0 – length of fabric before wet processing.

According to the method proposed, a circle is cut at the radius R in a square-shaped sample of unwashed colour.Notes are made every 15 degrees from its center to the direction of the beam thread. Such a circle is given in ***Figure 1***.

After heat-wet processing the circle will turn into a semicircular ellipse:

$$a = R(1 + \lambda_y) \quad b = R(1 + \lambda_o) \quad (2)$$

Here λ_y – linear dimension change according to beam thread, λ_o – linear dimension change according to weft thread.

Its equation is as follows:

$$\frac{x^2}{R^2(1+\lambda_o)^2} + \frac{y^2}{R^2(1+\lambda_y)^2} = 1 \quad (3)$$

Solving this equation together with that of the *OA* straight line will take the following from:

$$y = x tg\alpha \quad (4)$$

After recalculation:

$$x_B = \frac{R}{\sqrt{\frac{1}{(1+\lambda_o)^2} + \frac{tg^2\alpha}{(1+\lambda_y)^2}}} \quad (5)$$

$$y_B = \frac{R\,tg\alpha}{\sqrt{\frac{1}{(1+\lambda_o)^2} + \frac{tg^2\alpha}{(1+\lambda_y)^2}}} \quad (6)$$

(1) according to ***Equation (1)***, the deformation of threads in the direction of *OA* can be expressed as follows:

$$\lambda_\alpha = \frac{OB - OA}{OA}, \quad (7)$$

or

$$\lambda_\alpha = \frac{\sqrt{x_B^2 + y_B^2} - R}{R}, \qquad (8)$$

after replacing the x_B or y_B , we get the following ***Equation (9)***:

$$\lambda_\alpha = \frac{(1+\lambda_o)(1+\lambda_y)}{\sqrt{(1+\lambda_o)^2 \cos^2\alpha + (1+\lambda_y)^2 \sin^2\alpha}}. \qquad (9)$$

The anisotropy of the deformation of the fabric threads after heat-wet processing may be characteriaed as a coefficient of anisotropy:

$$k = \frac{\lambda_O}{\lambda_y}, \qquad (10)$$

Here, λ_y – linear dimension change according to weft thread, λ_o – linear dimension change according to beam thread.

The works [9, 10] checked the practical application of ***Equation (10)***, and the results of calculations were compared with the experimental results.

For the experimental samples, mainly linen fabrics were selected. These fabrics were combined with self-twisted elastic in the weaving system.

After removal from the weaving machine, the fabric samples were stored, shredded, and dried under normal conditions to relieve internal stresses generated during the weaving process. From the pieces made in this way, square samples with a side of 150-1 mm were cut. In the samples prepared using a template with indelible paint, marks in the form of a circle with a diameter of 100 mm and a dot in the center of this circle were applied. Samples prepared in this way were scanned at 300 dpi. The samples were then washed in accordance with the requirements of GOST 30157.1-95. Washing was repeated 7 times. After each wash, the sample was dried in a flattened condition to a nominal humidity and subjected to screening. Digital images of the samples obtained in this way were made in the center of the circle according to the directions of the raw material and the discharge. Comparison of the images obtained showed that after the fifth wash, the size of the samples was practically stabilised. The change in the linear dimensions of the sample was measured after the 7th wash to make sure that there was a complete change in the size of the sample due to moisture treatment.

Images of samples for processing were placed in the AutoCAD environment. Using the AutoCAD graphics editor, 15 radial lines were drawn from the midpoint in the direction of the tissue and beyond. Along these lines, the distance between the circle drawn on the sample before the test and the corresponding figure without shrinkage was measured. The experimental value of shrinkage was calculated by ***Equation (7)***, theoretically determined by ***Equation (9)***. Comparison of the samples obtained with a confidence level of 0.95 according to Fisher's test showed that the model of the change in linear dimensions represented by ***Equation (9)*** is adequate.

The fabrics were washed 7 times, and after every one the deformation was measured in the direction of the beam thread every 15° i.e. the angle of curves according to the beam thread degree (***Figure 2***).

The experiments were performed on cotton-based fabrics with a linear density of 25 tex, containing two types of yarns: linen 25×2 tex and self-wrapped yarn with elastane $(25 \times 2 + 7)$ tex. Knitted yarns with elastane were included in one, two, etc. clean canvas ropes. As a result, fabrics with an elastane content of 7.0, 2.61, 1.61 and 1.35% were obtained. The changes in linear dimensions for these threads are shown in ***Figure 2*** with curves 5, 4, 3 and 2, respectively. The curvature corresponds to the fabric without elastane, which does not leave 1 nest.

Conclusions

1. Analysing the available scientific literature sources, it was determined that the empirical formulas, which do not take into account the process of tissue deformation, do not allow to adequately calculate the settlement of tissues after wet processing in different directions from the base and utka directions.
2. As a result of theoretical analysis of the deformation process of the fabric with closure of the elastane, a dependence is proposed to calculate the settlement of the fabric in any direction.
3. The adequacy of the dependencies obtained is proved on the basis of the comparison of the calculation results based on the model proposed and experimental data.

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Received 04.02.2021 Reviewed 09.03.2021