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DETERMINATION OF LINEAR DIMENSIONS CHANGES IN HEAT-RESISTANT TEXTILE MATERIALS

Abstract. *This article contains the results of experimental researches as to the impact of operational factors on the properties of heat-resistant textile materials, such as changes in linear dimensions due to repeated wash cycles. It was found that the selected materials retained their properties to the extend, specified by regulatory documents. It was determined the mathematical relation between changes in linear dimensions and number of wash cycles and made their comparative analysis in order to predict the behavior of special clothing materials.*

Keywords: heat-resistant materials, protective clothes, washing, changes in linear dimensions.

I. Introduction

The range of textile materials for manufacturing of heat-resistant clothes is quite wide. Well-known companies constantly expand and improve the range of heat-resistant materials and their characteristics. Information about characteristics and properties of such materials is quite fragmented and presented mainly from the commercial point of view. Also the change of such materials parameters as a result of different operating loads is unknown.

II. Statement of the problem

Manufacturing of modern, high-tech clothing for protection against all identified types of hazards depends mainly on the used materials. The problem of rationally justified choice of materials is particularly acute for the passive protection method.

Manufacturers provide information about materials that do not consider the changes of properties in use. Such operating loads on the material include wet processing, washing in particular. In this regard the question of reliability indicators determination, namely the dependence between the changes in linear dimensions and the number of wash cycles, is of present interest.

III. Results

For the research foreign samples of heat-resistant materials with different ways of providing them with heat-resistance were selected. Therefore, textile materials, listed in Table 1, were selected as the subject of the research. When forecasting or evaluating the level of quality of special clothing, the preference was given to the stability of linear dimensions of its details during operation.

Table 1 – Characteristic of materials for protective clothes

Indicator name, unit of measure	Real value (characteristic) of the indicator			
	Nomex BV-120 (Nomex)	XB 9340 (Proban + Kevlar + anti-static)	FlameStat Lite (Proban + anti-static)	RigChief (Pyrovatex + anti-static)
Coded symbol	T1	T2	T3	T4
Type of processing	Nomex metaaramid fibers	Proban impregnation and Kevlar fibers	Proban impregnation	Pyrovatex impregnation
Content of raw ingredients, %	Nomex – 100	Cotton – 75 Kevlar – 25	Cotton – 100	Cotton – 100
Type of weaves	Twill	Sateen	Twill	Sateen
Surface density, g/m^2	265	340	250	370
Name of the company, country of origin	«Ten Cate Protect», The Netherlands	«Ten Cate Protect», The Netherlands	«Carrington», The United Kingdom	«Daletec», Norway

The research on determination of changes in linear dimensions was conducted in an accredited analytical and experimental testing laboratory «Textiles – Test» of KNUTD using a standardized method [4]. For the research basic samples size 300x300 mm were cut and the direction of warp thread was indicated. Using a template the marks were put at a distance of 200 mm on warp and on weft. The essence of the method was the determination of length of marks, printed on elementary sample of fabric after the wash cycle.

To determine the changes in linear dimensions of materials after washing, 4 types of materials, 6 samples of each were selected. The materials were subject to 12 wash cycles at 60 □C using standard washing agents. The changes in dimensions after processing were determined by the formula (according to [4]):

$$\lambda=((l_1- l_0)/ l_0) * 100, \qquad (1)$$

where λ – changes in dimensions after processing, %; l_1 – length of marks after wet processing, mm; l_0 – length of marks before wet processing, mm.

Change in dimensions is considered positive if the length of marks increases and negative if the length of marks decreases (process of furling).

Table 2 – Changes in linear dimensions based on the number of wash cycles

Number of wash cycles, n	Nomex BV-120		XB 9340		FlameStat Lite		RigChief	
	T1o	T1y	T2o	T2y	T3o	T3y	T4o	T4y
	In warp,%	In weft,%	In warp,%	In weft,%	In warp,%	In weft,%	In warp,%	In weft,%
1	-0,8	0	-0,6	-1,1	-0,3	0	-0,8	-0,3
2	-0,9	-1,0	-1,1	-2,5	-0,2	-0,8	-1,3	-0,3
3	-0,9	-0,5	-0,8	-1,4	-0,5	-0,3	-1,1	-0,8
4	-0,5	-0,3	-0,5	-0,9	-0,7	-1,1	-1,0	-0,5
5	-1,1	-0,8	-1,1	-1,3	-1,2	-1,8	-2,3	-1,1
6	-1,8	-1,5	-0,8	-1,5	-2,5	-0,8	-2,3	-1,3
7	-0,8	-0,8	-1,1	-2,6	-4,5	-1,3	-2,5	-1,3
8	-0,8	-0,8	-1,3	-2,3	-1,3	-1,5	-1,3	-2,6
9	-1,8	-1,5	-1,7	-2,8	-2,5	-2,4	-4,0	-2,0
10	-1,9	-2,0	-1,7	-2,5	-4,6	-1,9	-4,6	-2,3
11	-2,3	-1,7	-2,8	-3,1	-4,1	-2,3	-4,5	-2,3
12	-1,2	-1,3	-1,9	-2,1	-4,0	-1,8	-4,1	-2,5

The obtained data was processed by methods of mathematical statistics and graphs of dependence between the changes in linear dimensions of heat-resistant textile materials in warp To (fig. 1) and in weft Ty (fig. 2) and the number of wash cycles were obtained as well.

As a result of statistical analysis the following regression equations were obtained for different types of materials in warp with coded symbol:

T1o: $y=0.0117x^2-0.2799x$, when $R^2=0.2945$

T2o: $y=0.0009x^2-0.1957x$, when $R^2=0.631$

T3o: $y=-0.0072x^2-0.286x$, when $R^2=0.7091$

T4o: $y=-0.002x^2-0.358x$, when $R^2=0.7757$

As a result of statistical analysis the following regression equations were obtained for different types of materials in weft with coded symbol:

T1y: $y=0.0054x^2-0.201x$, when $R^2=0.5927$

T2y: $y=0.0237x^2-0.4918x$, when $R^2=0.1851$

T3y: $y=0.0083x^2-0.2769x$, when $R^2=0.7347$

T4y: $y=0.001x^2-0.2325x$, when $R^2=0.881$

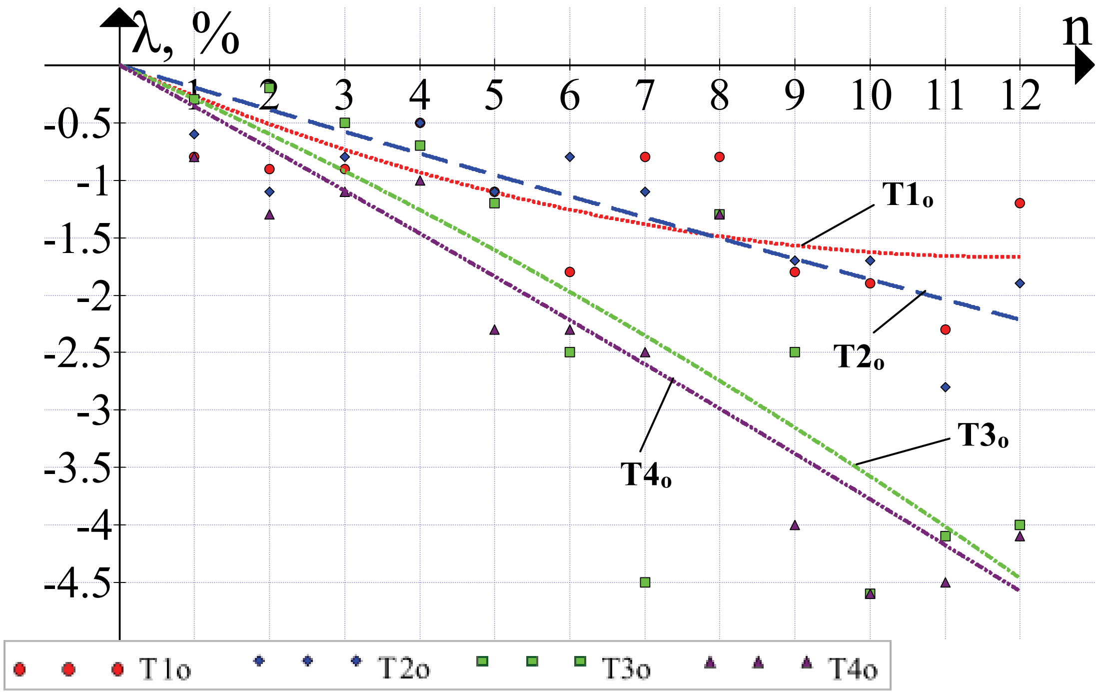

Figure 1 – Graphical interpretation of dependence between the changes in linear dimensions of materials in warp and the number of wash cycles

The graphs show that materials with coded symbols T3 and T4 have maximum deviations. Although the values of such materials do not exceed the norms (up to 5 %), but it causes the rejection of their application in the future. The fabric with coded symbol T1 has the best results, namely up to 2,3 % in warp and up to 2 % in weft, which means that it will not reduce the ergonomics of the design due to the reduction of linear dimensions after wet processing.

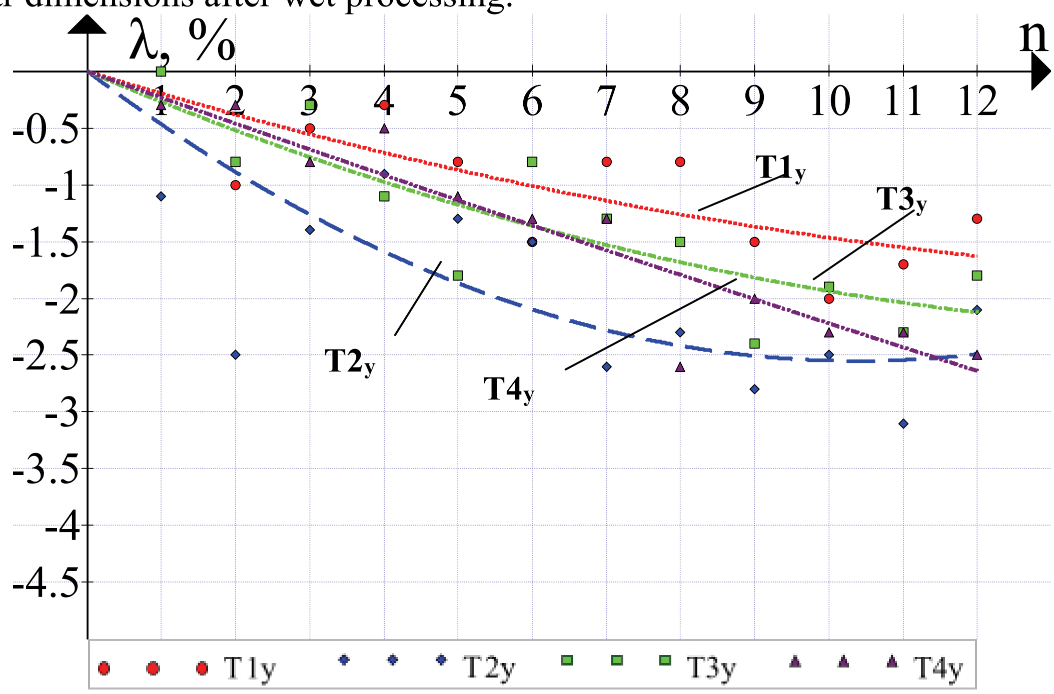

Figure 2 – Graphical interpretation of dependence between the changes in linear dimensions of materials in weft and the number of wash cycles

It was experimentally demonstrated that selected materials changed their properties after 12 wash cycles, but the values of those changes did not exceed the norms.

Analysis of the results made it possible to determine the nature of properties changes of fabrics after wet processing (washing) and take them into account when designing the protective clothes for conducting accident rescue operations.

IV. Conclusions

Conducted experimental researches on determination of dependence of changes in linear dimensions on the wet processing made it possible to state that all selected materials could be used in production of protective clothes for conducting accident rescue operations, but Nomex BV-120 had the best qualities. It was proved that wet processing (washing) had an influence on the changes in linear dimensions of materials; such influence was of different character and didn`t exceed the norms, and for the materials from metaaramid fibers was less meaningful. Based on the analysis of the changes in linear dimensions of different materials, it was found that moderate decrease after wet processing took place for almost most of them due to the small shrinkage of fibers along with the increase of their crimpiness.

The researches aimed at determination of changes in different parameters of packages of materials depending on the period of their operation, on frequency of the contacts with hazardous and harmful production factors etc. are quite perspective.

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