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Influence of Industrial Washing on Denim Properties

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One of finishing methods applied on fabric or garment is industrial washing, which together with the use of new technologies and equipment enables to obtain the desired results. Usually, washing is applied for already sewn garments, therefore, it is very important to know the impact made by particular washing on the fabric in order to preserve the quality of a sewing garment. A presumable change of properties shall be considered even in the phase of garment design. The aim of this paper is to determine the influence of different methods of industrial washing on denim properties. Currently popular and fashionable denim (twill 1/2 weave, composition 98 % cotton, 2 % elastane) was chosen for this investigation. The denim has been processed by different industrial washing techniques, namely simple and silicone softening, washing with chlorine solution, enzyme and double enzyme washing. In order to evaluate influence of different washing on fabric properties, the structural characteristics, shrinkage, air permeability, bending rigidity, extensibility on load 98.1 N/m, breaking force and elongation, shear rigidity has been determined. It can be concluded that the silicone softening made the greatest influence on the change of denim properties, whereas the simple softening the least one.

Keywords: industrial washing, denim fabric, physical mechanical properties.

INTRODUCTION

Industrial washing is one of the finishing methods applied on fabric or garment, which together with the use of new technologies and equipment enables to obtain the desired results. For finishing of denim fabrics, a range of treatment methods is used. They all are aimed at new possible effects of fabric appearance, namely millwash or rinsewash, stonewash, moonwash, sandwash, bleach, overdyed-look, damaged-look, scrubbed-look [1]. The greatest influence is made by washing on wear, hygienic and mechanical properties of items. During the whole washing cycle, garments are affected by the entire complex of different factors such as a washing solution, abrasion, creasing, heat, various chemicals, etc. Therefore, intensive destruction of polymers that are the components of fibres takes place and leads to intensive wear of articles. Garments from short fibres feature more intensive wear and tear as in the process of washing fibres are released gradually.

In recent years, there has been increasing interest in the use of environmentally friendly, nontoxic, fully biodegradable enzymes in the modern textile technology finishing process. Enzymatic treatment can replace a number of mechanical and chemical operations, which have been applied to improve the comfort and quality of fabrics by now [1, 2]. In the textile industry enzymes are applied mainly to get a cleaner fabric surface with less fuzz, to reduce tendency to pill formation, to improve handle, to smooth the surface combining with traditional softeners. The development studies of this area have been focused on applying enzymes on cellulose materials based on cotton, linen, viscose and their blends with synthetics fibres [3– 8].

To improve fabric handle, technological and exploitation properties the softeners are widely used in finishing operations [9]. A nice, appealing handle is often the critical criterion for buying a textile. Consequently in the research works, influence of softeners on the change of handle is analysed [10 – 12].

Usually, finishing is applied for already sewn garments, therefore, it is very important to know the impact made by particular washing on the sewing garment fabric in order to preserve the quality of a sewing garment. This will be considered even in the phase of garment design. In modern sewing industry, washing is applied to articles of cotton, linen and other fabrics.

Many of the recently published papers analyse the change in colour of textiles after applying to them different finishing methods as clients upon choosing an item at shop always pay attention to its colour [11 – 14]. One or another shade has a great influence on the buying decision of a customer. In the course of wear, mechanical properties of fabric that determine durability and aesthetical view of an article are also important. Solution of the latter problem, however, is not considered. Such factors as using up by abrasion, pilling are analysed in [18]. However, the latter factors might have positive influence on denim either, as for the time being detritions in some places or over entire garments are applied purposively. They have become fashionable in the production of both denim and other clothing. Extensibility, rigidity, strength, shrinkage, air permeability of denim are very important properties, however, influence of industrial washing on their change was not evaluated.

The aim of the paper is to determine the influence of different methods of industrial washing on denim properties.

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EXPERIMENTAL

The investigation has been carried out with currently popular and fashionable denim. Basic characteristics of selected fabric are shown in Table 1.

Table 1. Characteristics of unwashed denim

Fabric code		A1
Composition		98 % cotton, 2 % elastane
Weave		twill 1/2
Density, dm^{-1}	warp	210
	weft	250
Surface density, W, g/m^2		371
Linear density, tex	warp	99
	weft	32

The denim has been processed by different industrial washing techniques, which are often used for final finish of denim garments in these days. These techniques were simple and silicone softening, washing with chlorine solution, enzyme and double enzyme washing (Table 2).

Table 2. Descriptions of denim industrial washing techniques

Fabric code	Name	Description
A2	Simple softening	Vinegar acid of 98 % is used, PH is measured – (4.5 – 5), any softener is poured into the cold water and the temperature is raised up to 38 – 40 °C. Softening takes place for 10 – 20 min. The water is drained, items are dried in normal conditions, on the hangers.
A3	Washing with chlorine solution	Washing is carried out during 4 stages. During the first stage, sizing is performed, chemicals are put in, enzymes are stirred in, and the time is 20 min. at 60 °C. During the second stage, enzymes and perlites are introduced. Temperature is raised up to 60 °C and items are turned for 50 min. During the third stage, rinsing is carried out and enzyme operation is being stopped. During the fourth stage, softening takes place for 20 min at 40 °C.
A4	Enzyme washing	This one is analogous to the A3 washing, only without perlites being stirred in, and without any other chemicals
A5	Double enzyme washing	The washing is carried out during 2 stages. During the first stage, enzyme introduction takes place, the samples are washed for 20 min at 55 °C, rinsing is performed twice and in the cold water for 3 min. During the second stage, neutral enzyme introduction takes place; washing is carried out for 30 min. at 60 °C. Rinsing is performed twice, in cold water for 5 min.
A6	Silicone softening	To obtain greater mechanical effect, less water should be used. Washing is carried out with cation softener for 8 min., at 40 °C.

The fabric thickness $T2$ (mm) was measured in accordance with FAST system [19, 20], density P_1, P_{20} (dm^{-1}) in accordance with LST EN 1049–2, surface density W (g/m^2) in accordance with LST EN 12127.

Fabric shrinkage S (%) was determined in accordance with LST EN 3759. Air permeability A (dm^3/h) was measured with air permeability measurement device ATL–2, at 50 Pa pressure.

The determination of breaking force F (N) and elongation at break ε (%) was obtained following the standard LST ISO 13934–1. The tensile characteristics of specimens were measured using universal testing machine ZWICK/Z 005. All experiments were carried out in standard atmosphere for testing according to the standard ISO 139. The specimens used for tensile investigation were cut in the warp and weft.

In order to evaluate influence of different washing techniques on changes of denim properties, the bending rigidity B (μNm), extensibility $E100$ (%), on load 98.1 N/m, shear rigidity G (N/m) were determined according to the FAST methodology.

RESULTS AND DISCUSSION

To assess the influence of different washing techniques on denim properties, changes in structural and certain physical mechanical properties were determined.

Structural characteristics of denim before and after industrial washing are presented in Table 3. Amount of the specimens were 6, the coefficient of variation did not exceed 2 %. The provided results demonstrate that different washing methods make different influence on the denim thickness $T2$. After simple softening, thickness $T2$ increased by 12.5 %, whereas after washing with a chlorine solution it increased by some 7 %. Enzyme washing conditioned fabric thinning, whereas in other cases thickness $T2$ changed negligibly. Such results may be determined mainly of the impact of the chemical used in the investigation. Enzymes removed impurities and individual loose fibre ends and smoothing the surface, which caused the thinning. Softener precipitates on the yarns, therefore fabric thickness increase.

In all the cases analysed, density P and surface density W of fabric increase. The greatest influence on increase of the surface density W was made by washing with a chlorine solution (14 %) and by silicone softening (13 %).

Table 3. Structural properties of denim before and after washing

Fabric code	Thickness * $T2$, mm	Density, dm^{-1}		Surface density W, g/m^2
		P_1	P_2	
A1	1.20	210	250	371
A2	1.35	220	270	410
A3	1.28	240	290	423
A4	1.12	220	280	413
A5	1.16	230	270	416
A6	1.16	230	280	419

*at 1.96 Pa pressure.

Surface thickness ST shows roughness of fabric surface, structural stability of a surface layer. In this experiment amount of specimens were 6, the coefficient of variation did not exceed 2 %. Analysis of the obtained results (Fig. 1) allows stating that only thickness (0.49 mm) of the fabric treated by simple softening is higher than the surface thickness *ST* of unwashed denim, whereas all other treatment methods led to the decrease of this characteristic. The highest influence on the change of the surface layer size was made by enzyme washing and silicone softening. After that, the greatest reduction in thickness was observed, i.e. from 0.42 mm down to 0.27 mm – 0.28 mm. After simple softening, thickness of the surface layer increases by 17 %.

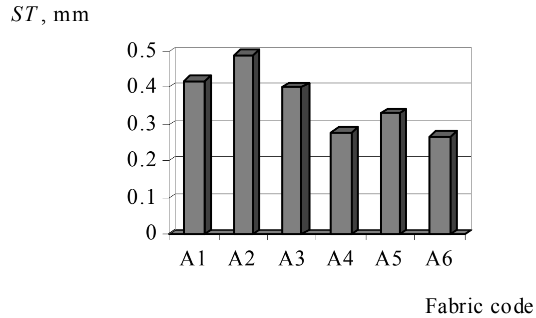

Fig. 1. The results of surface thickness *ST*, mm

In the phase of garment design, it is necessary to assess fabric shrinkage; otherwise dimensions of a ready-made article will mismatch the designed ones. Results of the denim shrinking capacity after industrial washing are presented in Table 4.

Table 4. The results of shrinkage *S* of denim after washing

Fabric code	Shrinkage *S*, %	
	warp	weft
A2	1.8 ±0.1	4.5 ±0.1
A3	2.4 ±0.1	4.7 ±0.1
A4	2.3 ±0.1	4.6 ±0.1
A5	2.0 ±0.1	4.6 ±0.1
A6	2.9 ±0.1	5.1 ±0.2

Analysis of the obtained results demonstrates that upon the influence of washing a garment shrinks, however, with different shrinkage value. Shrinkage *S* in the weft exceeds the allowable standards (allowable standard is 2 % according to LST EN 25077:1996). Consequently, even in the phase of article design it is required to assess shrinkage in this direction. In the warp, shrinking capacity stays within the allowable standard, i.e. 3.5 %. Denim shrinkage after washing is closely related to the change in its structural characteristics.

The obtained results demonstrate that air permeability *A* after washing decreased in all cases (Table 5). The lowest change of air permeability *A* in fabric is observed after simple softening, whereas the highest change is noticed after double enzyme washing.

Such decrease of air permeability *A* also depends upon changes of structural properties of fabrics. After industrial washing fabrics has been shrunk, therefore the density *P* and surface density *W* increase. Analysing the influence of surface density on air permeability, it was observed the inversely proportional relationship between the mentioned characteristics (Fig. 2). It was found, that air permeability decreased by 45 % in some cases.

Results of elongation *E*100 at small loads demonstrate that even in the initial phase of tensile in the weft, fabric treated with different washing ways features higher elongation, whereas in the warp influence of washing was not so significant (Fig. 3). After washing, elongation *E*100 in the weft increased almost twice in some cases, whereas elongation *E*100 in the warp was negligible. The amount of specimens was 6, coefficient of variation was from 0.51 % till 4.88 %.

Table 5. The results of air permeability *A* before and after denim washing

Fabric code	A1	A2	A3	A4	A5	A6
A, dm^3/h	850	680	600	535	470	580
Coefficient of variation, %	6.79	5.14	7.86	4.50	5.49	7.27

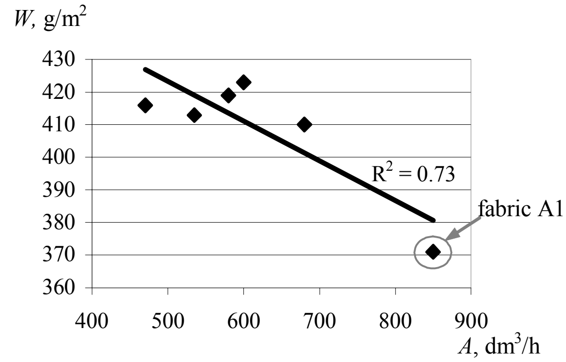

Fig. 2. The effect of surface density *W* on air permeability *A*

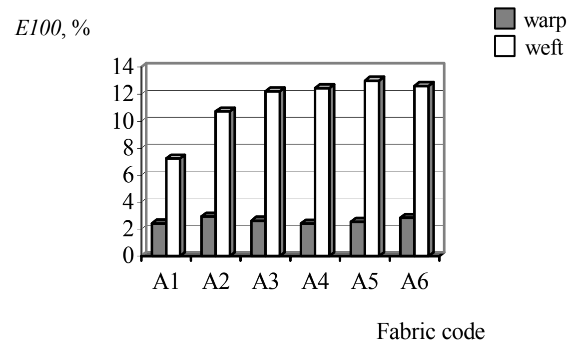

Fig. 3. The results of elongation *E*100, %

The breaking force *F* in the warp and weft is very different, too (Fig. 4). In this case the coefficient of variation was from 2.25 % till 6.28 %. In general case, silicone softening and washing with a chlorine solution had the lowest influence on the fabric breaking force *F*. Simple softening led to increase of breaking force *F*, whereas double enzyme washing stipulated its decrease. The greatest decrease in fabric strength between all the cases analysed was observed in the weft, i.e. 45 %. The obtained results may be explained by the mechanism of double enzymatic washing. Enzymes are surface-active and in the first stage of washing they will most probably act on the outer surfaces of the yarn. During second washing enzymes will react on the increased surface area and damage the yarn. It caused strength loss of fabric.

It was obtained that in all the cases breaking elongation ε increased: in the warp, it increased less

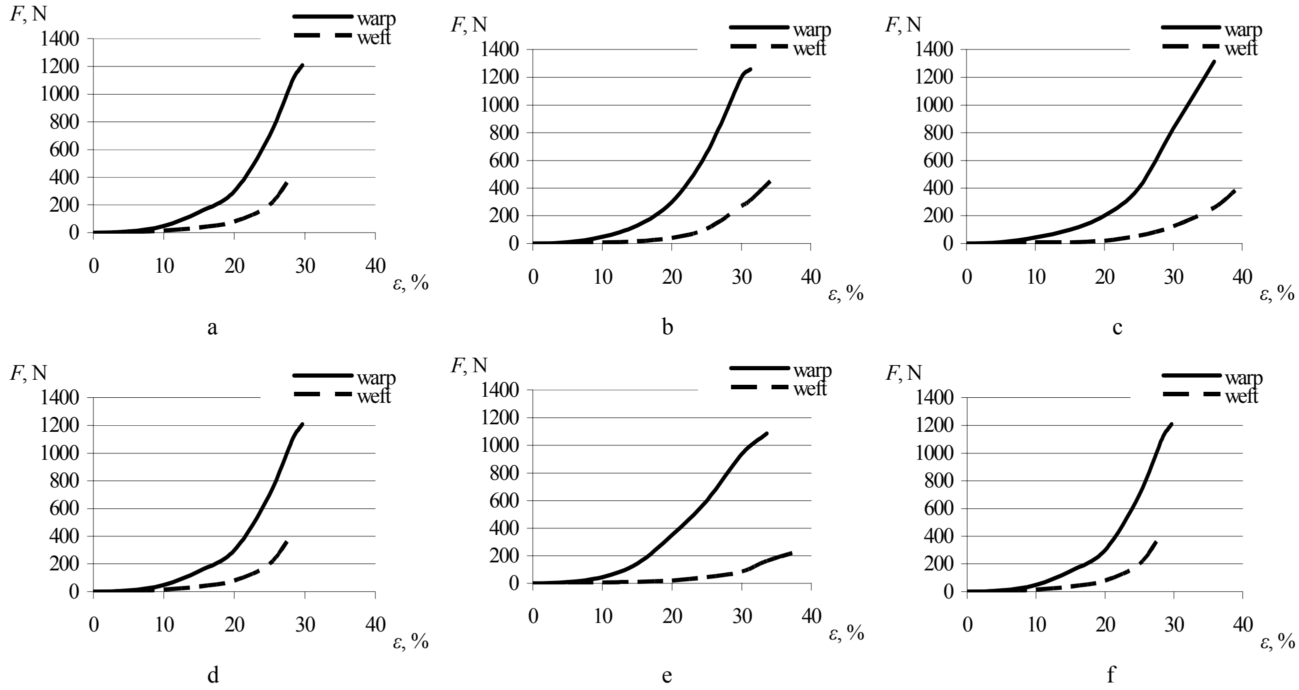

Fig. 4. Tensile diagrams of the fabrics: a – A1, b – A2, c – A3, d – A 4, e – A5, f – A6

(5 % – 21 %, compared to the original) and in the weft, it increased more (17 % – 39 %).

The greatest elongation *ε* in both directions was obtained in the fabric washed with a chlorine solution. The lowest influence on the change of breaking elongation *ε* was made by silicone softening. The coefficient of variation was from 1.53 % till 6.63 %.

The obtained results of bending rigidity *B* are presented in Fig. 5. The coefficient of variation of results does not exceed 5.77 %. This characteristic is especially important upon selecting the construction of a garment as increase in fabric rigidity leads to worse drape of a garment. The lowest and highest bending rigidity *B* of denim was determined in the weft and in the warp correspondingly.

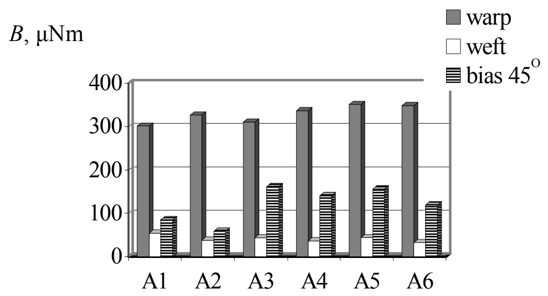

Fig. 5. The results of bending rigidity *B*, μNm

After all washing modes, bending rigidity *B* of fabrics in the warp increased, whereas in the bias 45° direction bending rigidity *B* also increased excluding the case after simple softening when it decreased by 31 %. In the weft, values of the aforementioned characteristic decreased. From all the treatment methods applied to denim, the greatest influence on the bending rigidity was made by silicone softening: in the warp, rigidity *B* increased by some 16 %, whereas in the weft, rigidity decreased by some 40 %. Very similar results were also obtained after double enzyme washing. In the bias 45° direction, the highest increase in bending rigidity *B* was observed after washing with a chlorine solution and after double enzyme washing. The obtained results can be explained by the changes of fabric structural properties after washing. The fabric became denser, surface density *W* and thickness *T*2 increase, which caused the fabric rigid in most cases. In some directions stiffness decrease after simple and silicone softening. It may be related to the influence of the softeners, which impact the fabric.

Shear rigidity *G* results presented in Fig. 6. In this case the coefficient of variation does not exceed 1.29 %. It was observed that shear rigidity of all fabrics after washing decreased compared to shear of untreated fabric.

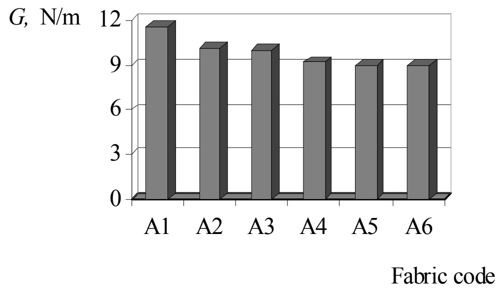

Fig. 6. The results of shear rigidity *G*, N/m

After double enzyme washing and silicone softening, shear rigidity *G* decreased down by 22 % (at the maximum), whereas after enzyme washing it decreased by 21 %. In other cases of industrial washing shear rigidity decreased also, but less (by some 10 %). On the basis of the above, it may be stated that handle of fabrics are better after washing.

The obtained results demonstrate that different methods of industrial washing make different influence on the change of denim fabric properties and at the same time on the properties of a ready-made garment.

CONCLUSIONS

1. The investigation allows stating that the greatest influence on the change of denim properties was made by silicone softening. After this washing, the fabric shrinks most of all (till 5 %), which caused the considerable changes of structural properties and herewith bending rigidity and shear. Similar results were obtained after double enzyme washing.
2. From all the treatment, the enzyme washing made the greatest influence on the change of thickness, denim became the thinnest. The lowest breaking force obtained after enzymatic treatment may be caused by impact of the surface-active enzymes, which damages the yarn.
3. Washing with a chlorine solution mostly influenced the change of denim structural properties. As it is known, this method of washing should be avoided due to its harmful effect on human health, therefore, referring to the obtained similar results its replacement with simple softening or enzyme washing might be recommended.
4. Simple softening has not significantly affected fabric properties, except the fabric thickness. The increase of this characteristic could be determined by surface layer increase, which in this case was the highest.
5. Both visual and functional purpose of a garment may be assessed whereas selection of a particular method of industrial washing influenced different fabric properties.

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