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# The Influence of the Technological Treatment Regime on the Mechanical Properties of Textile Fabrics

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The behaviour of the woven and knitted textile fabrics during the washing process was investigated. The influence of the washing regime and the cationic chemical softener on the mechanical properties of the textile materials was determined. The relationship between the main parameters of the punch process defined by the original device KTU-Griff-Tester and the geometrical and mechanical properties of materials was analyzed. The influence of the washing temperature on the changes of the specimen mass, thickness and flexibility properties was presented. The influence of electricity of fiber materials on the friction parameters determined under measurements of standard DIN 53375 was investigated. The analysis of the friction parameters when the specimen was sliding through the different stands was done. It was defined that the device KTU-Griff-Tester enables to evaluate the changes of mechanical properties of the textile fabrics after the washing, softening and other relatively sensitive actions during exploitation period.

*Keywords*: textile, hand, friction, flexibility, cationic softeners.

## INTRODUCTION

The textile fabrics during the cycle of their exploitation follow under multifold hydrothermical treatment (washed), which increase wearing duration improves the hygienic properties and aesthetic appearance of the product. Such a treatment can decrease mechanical properties of the fabrics: it stimulates shrinking, increases the surface roughness, decreases the fabric flexibility, etc.

Many industrial chemical softeners are used. As a rule they are mostly of cationic activity and they effectively reduce the process of the properties deterioration due to the washing [1, 2].

One of the most reliable and secure methods to control the properties changes of the textile fabrics due to the washing is the measurement of the hand parameters. The washing, cleaning or some other kind of the treatment does not change the resistance characteristics of the textile fabrics but it significantly changes the hand parameters [3 – 9].

Consistent patterns evaluation of change of hand parameters after washing could allow choosing rational washing powder and technological treatment regimes.

The aim of this work was to determine the influence of the washing regime and cationic chemical softener on the mechanical parameters of textile fabrics.

## MATERIALS AND METHODS

The objects of investigations were 4 woven and knitted fabrics which main characteristics are presented in Table 1 and Table 2.

The technological treatment used was: washing and immersion in the solution of chemical softener. Two samples of each experimental fabric (40 cm × 60 cm) were washed. Control specimens (C) were cut from original fabrics without any technological treatment. Automatic washing machine "Fagor" was used. Washing was performed at water temperature of 30, 60 and 90 °C ($W^{30}$, $W^{60}$, $W^{90}$). Washing powder "Ariel" (Czech Republic) in equal doses in each test replication was used. After the washing half of the samples were immersed in the softener "Lenor" (Czech Republic) for duration of 20 minutes ($W^T$ +S). The concentration of the softener "Lenor" was 1.8 ml/l $H_2O$ as defined by the producer. The washed samples were dried in the horizontal position and were used to cut of specimens and to measure the parameters of the hand, flexibility, friction and electric charge. The disc-shaped specimens were cut for evaluated hand parameters (disc radius $R$ = 56.5 mm).

The friction experiments were performed with a tensile testing machine Zwick/Z005 according to the requirement of DIN 53375, hand experiments were performed with an original device KTU-Griff-Tester [10 – 13] and values of fabric strip bending length $c$ [mm] was measured using conventional cantilever principle, as described in British Standard Method (BS:3356) [14, 15]. The velocity of pulling for friction test was 500 mm/min and for hand test it was 100 mm/min.

Two pads: glass (G) and poly methyl metacrylate (PMMA) plate (same as used for the bearing plates of KTU-Griff-Tester) were used in the friction experiment and friction curve was registered and friction parameters were calculated using commercial software *testXpert*®.

The test regimes with KTU-Griff-Tester were chosen in accordance to the specimen thickness $\delta$, which determines the values of the radius of the pads hole $r$ and distance between the limiting plates $h$ parameters (when $r$ = 10 mm, $h = 5.6\delta$; when $r$ = 7.5 mm, $h = 7.5\delta$). The hand of the test objects was estimated according to five parameters defined from the pull curve $H$-$P$ (deflection-power): maximum extraction force $P_{max}$, maximum deflection height $H_{max}$, the tangent of nominal slope angle

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**Table 1.** Materials properties

| Fabric symbol | Fabric type | Fabric content | Weave/Knitting type | Fabric density, $cm^{-1}$ | |
|---|---|---|---|---|---|
| | | | | Warp /Wale | Weft /Course |
| CO-W | Woven fabrics | 100 % cotton | Twill | 39 | 23 |
| LI-W | | 100 % flax | Plain | 18 | 18 |
| CO-K | Knitted fabrics | 100 % cotton | Plain jersey | 12 | 16 |
| PA-K | | 100 % polyamide | Warp-knitted locknit | 15 | 20 |

of the curve tg$\alpha$, the deformation work $A$ (the area under the curve) and the complex hand parameter $Q$ [10 – 13]. The change and stability of the investigated parameters were relative compared to parameters of control specimen (C) which was equating to 1.

As the interaction of the cationic softener with the textile fabric depends on the electric charge of the fabric surface, this parameter was controlled with the electrostatic field-meter FMX-002 (the Netherlands).

For each point 6 – 10 samples were tested. Such number of samples has always ensured the error level within the limits of 5 %. Fabrics were tested and evaluated under controlled environmental conditions (20 ±2 °C, 65 ±2 % r.h.).

## RESULTS AND DISCUSSIONS

The control parameters of the test objects are given in Table 2. The table shows the comparison of the following parameters: pulling through a hole, geometrical, friction and electrostatic charge of the surface.

The data in Table 2 show that the parameters of the pulled through the hole woven fabrics significantly differ from those of the knitted fabrics pulled through the hole samples. The parameters $P_{max}$, tgα, and $A$ differ up to 3 – 4 times. This is related to the structure peculiarities and deformation properties. In all the test cases the dynamic friction coefficient of fabric with glass (G) was greater than that using PMMA plate.

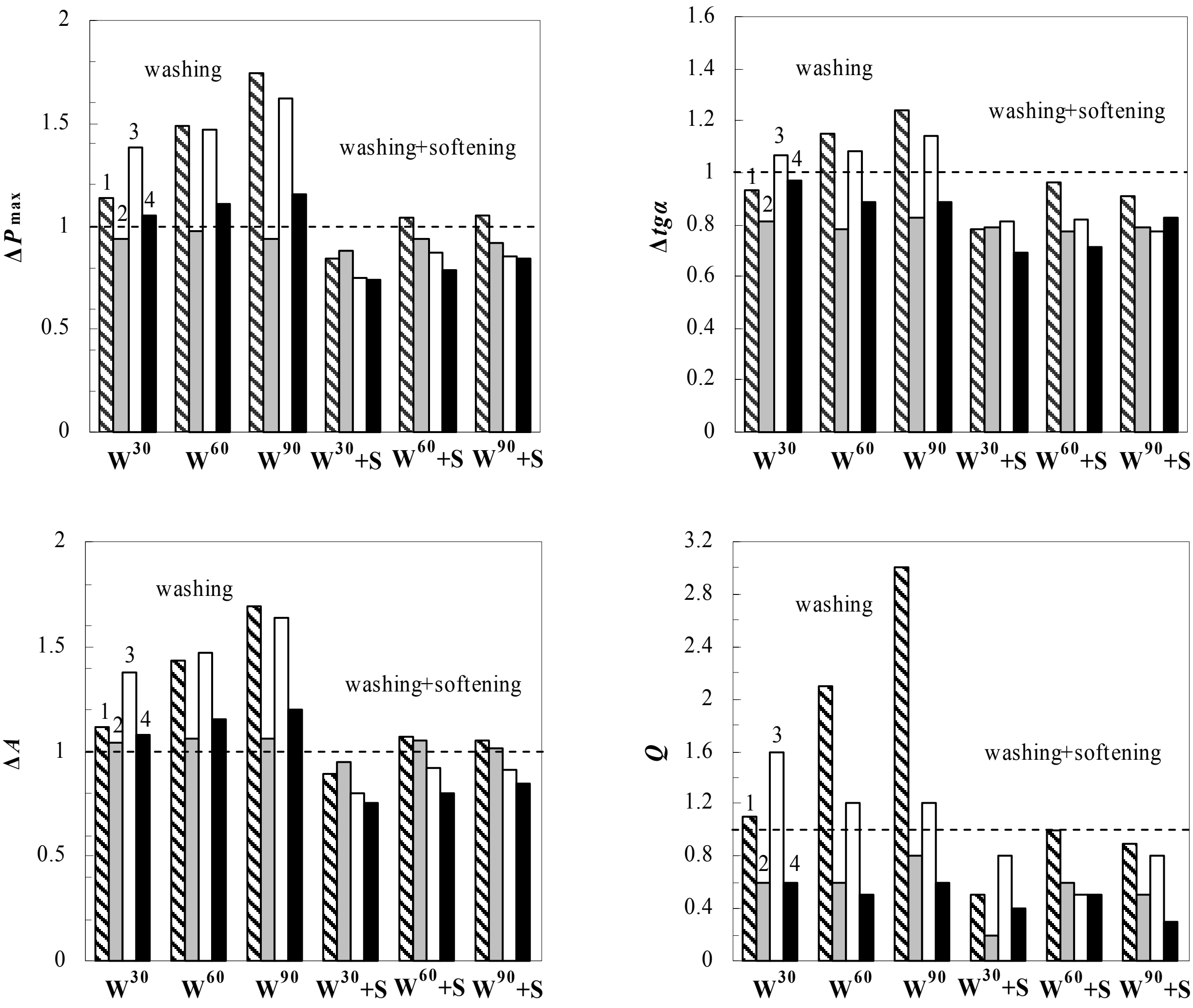


**Fig. 1.** The dependencies between the main hand parameters $P_{max}$ , tgα, $A$, $Q$ of textile fabrics (1 – CO-W, 2 – LI-W, 3 – CO-K, 4 – PA-K) and the washing temperature

**Table 2.** Control parameters of the investigated materials

| Fabric symbol | Hand parameters | | | | Geometrical parameters | | Dynamic friction coefficient $\mu_D$ | Sign of electric charge of fabric surface |
|---|---|---|---|---|---|---|---|---|
| | $P_{max}$, N | tgα | $A$, Ncm | $H_{max}$, mm | $W$*, g/m$^2$ | $\delta$, mm | G/PMMA** | |
| CO-W | 20.5±0.4 | 16.168±0.4 | 71.7±2.1 | 56.6±1.0 | 208±3 | 0.47±0.01 | 0.27/0.21 | – |
| LI-W | 14.5±1.2 | 13.838±0.7 | 46.9±2.7 | 56.4±2.0 | 210±2 | 0.45±0.01 | 0.31/0.15 | + |
| CO-K | 6.0±0.1 | 2.961±0.2 | 19.7±0.5 | 61.4±1.1 | 107±1 | 0.46±0.01 | 0.32/0.16 | – |
| PA-K | 3.8±0.4 | 2.184±0.3 | 14.2±1,5 | 58.1±2.8 | 60±1 | 0.27±0.01 | 0.34/0.23 | – |

Notes: $W$* – area density; G/PMMA** – glass/PMMA stand.

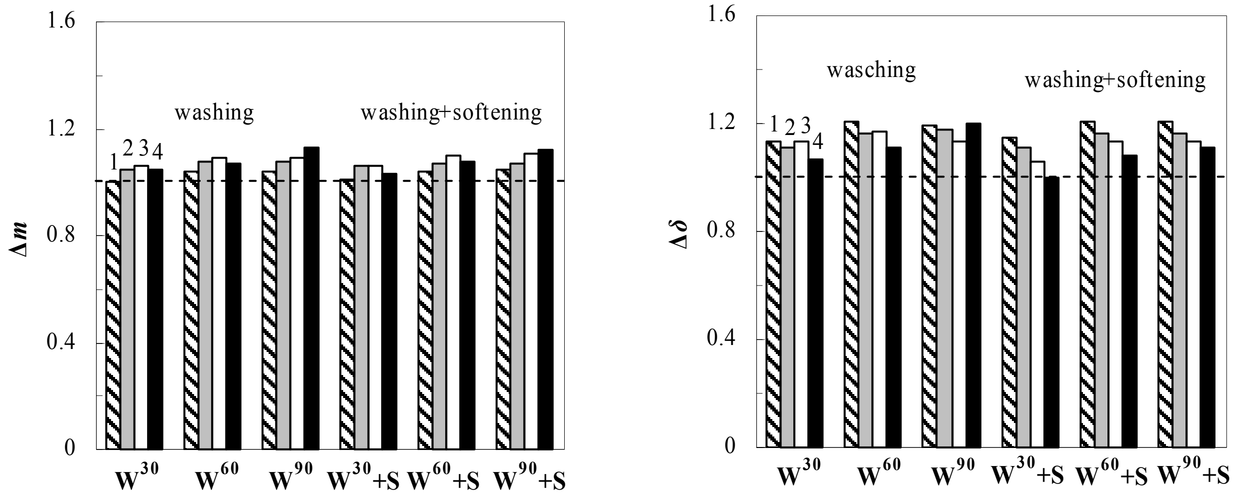


**Fig. 2.** The dependencies between the mass $m$ and thickness $\delta$ of the sample (1 – CO-W, 2 – LI-W, 3 – CO-K, 4 – PA-K) and the washing temperature

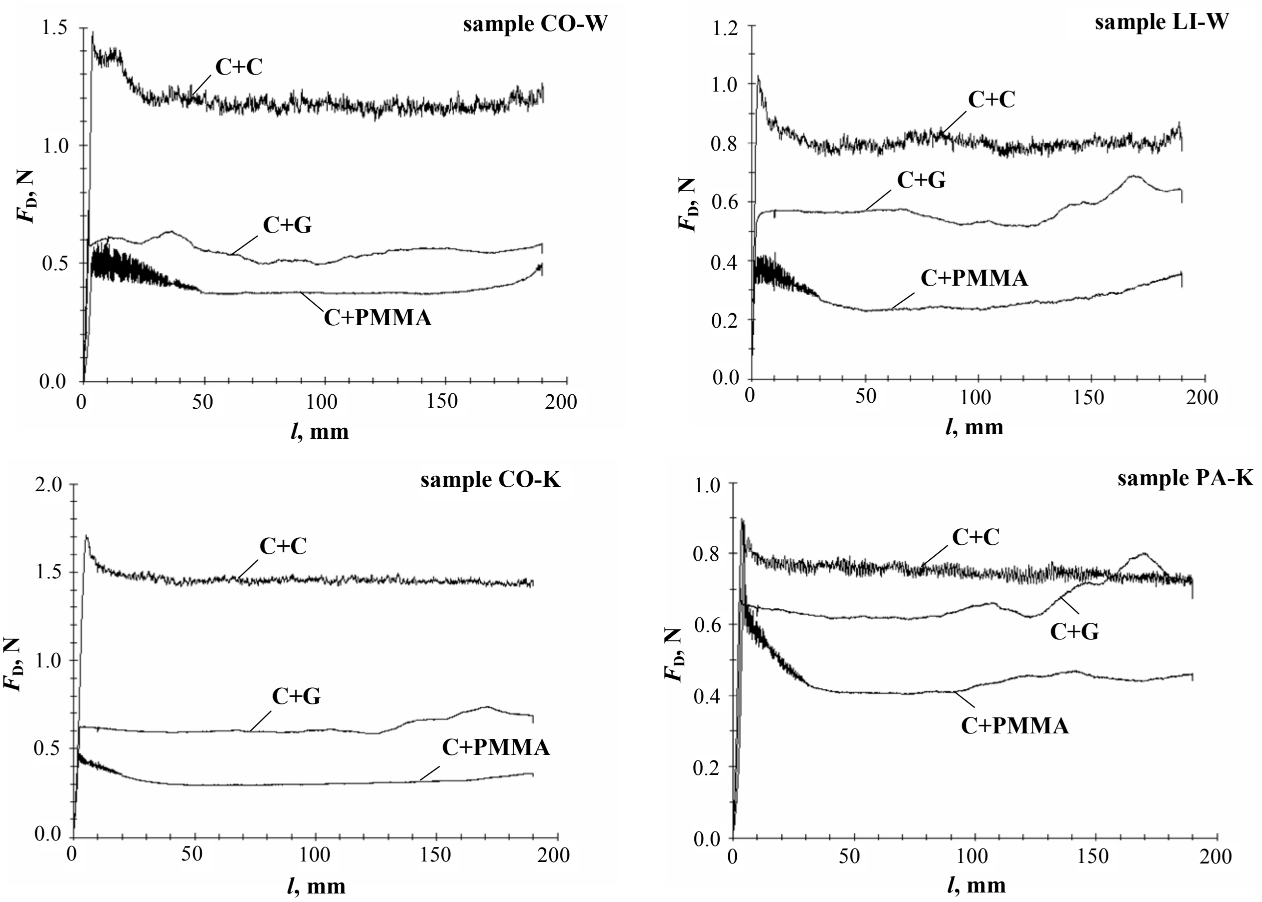


**Fig. 3.** The friction curves of identical control fabric (C+C), woven (a, b) and knitted (c, d) fabrics during their sliding across the surfaces of glass (C+G) and PAAM plate (C+PMMA)

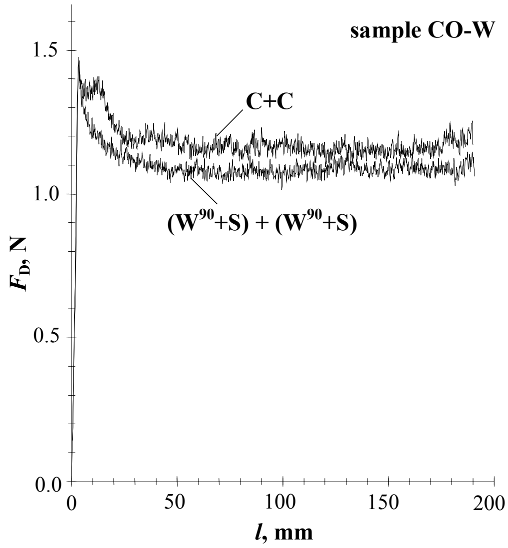


**Fig. 4.** The friction curves of the woven fabric before the washing in the pair with identical control fabric (C+C) and after the washing at the water temperature of 90 °C and softening ($W^{90}$+S)

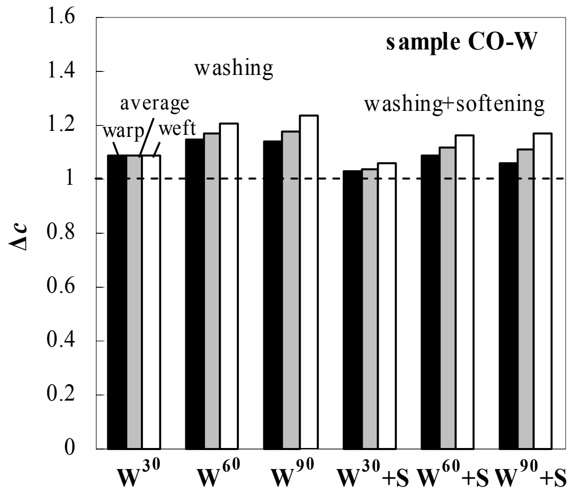


**Fig. 5.** The dependencies between the values of fabric bending length *c* and washing temperature

The measurements of the electrostatic charge showed that only the linen woven fabric LI-W had a very low positive charge and the other fabrics were charged negatively, i.e. they had a low negative electrostatic charge on the specimen surfaces.

When the investigated fabrics were additionally immersed in the solution with cationic liquid softeners the initial parameters of the investigated materials significantly changed (Fig. 1, 2). The main punch parameters $P_{max}$, tgα and *A* of the whole test objects increase when the washing temperature increases. It can be related to the increase of thickness of the specimen fabric. The use of the softener "Lenor" gives the opposite results. All three parameters decrease and approach the level of the control parameters. The exception was only the sample LI-W because all its parameters did not change significantly independently on the number of washing and softening cycles. The parameters $P_{max}$ and tgα during all the tests were lower or very close to those of control ones. This, obviously, could be explained by the intensive wash out of the finish materials during the washing and impossible link of the cationic softener because of the positive charge on the material surface.

It should be noted that in all the cases (except CO-W) the chemical softener reduces the main hand parameters $P_{max}$, tgα, *A* and *Q* to values less than 1.0, i.e. it improves the hand level as compared to the control samples. It was estimated that the washing temperature has linear relationship with many measured mechanical parameters but mechanical properties do not always depend on the washing process regimes. Exception from this only for fabric LI-W was found (Fig. 1).

The analysis of friction parameters (Fig. 3) shows that the form of the friction curves and the values of the coefficient of dynamic friction $\mu_D$ and the force of dynamic friction $F_D$ depend on the stand through which the fabrics slide. When the sliding pairs are identical fabrics (C+C) the friction parameters get maximum values. When the textile specimen slides through the glass surface (C+G) the friction parameters have the intermediary positions, and when the textile fabric sample slides through the PAAM plate (C+PAAM) the values of the measured parameters are the lowest. Two different kinds of glasses are chosen here as the prototypes of the limiting plates of the device KTU-Griff-Tester. The glass stand shows the significant variation of the dynamic force $F_D$ that is related to accumulation of the electrostatic charge and pulsation of the electric charge during the sliding process. In the some cases $F_D$ for C+G exceeds $F_D$ found for C+C (Fig. 3).

The analysis of the friction parameters showed that the washing process (when all kinds of the stands were used) always increased the friction coefficient $\mu_D$ and the dynamic friction force $F_D$. The increase reaches up to 13 % – 16 % when samples CO-W, LI-W, PA-K were used. The use of the softener "Lenor" does not improve the situation and practically does not reduce the sliding parameters (Fig. 4).

The data of the fabric CO-W strips in the weft and warp directions showed that the increase of the washing temperature worsens values of fabric bending length *c* and the softener improves the flexibility properties (Fig. 5).

## CONCLUSIONS

When the temperature of the washing solution is raised, the specimen resistance to the pull through a hole increases (all the parameters that characterize the hand become worse, some of them up to 60 % – 75 %). Exception was only the linen fabric and its hand parameters: maximum extraction force $P_{max}$, the tangent of nominal slope angle of the pull curve tg*α* and the complex hand parameter *Q* after the washing reduced less if compared to the level of the control specimens without any technological treatment and in all the range of the temperatures it actually remained in the same level.

After the use of the softener "Lenor" all the hand parameters: maximum extraction force $P_{max}$, maximum deflection height $H_{max}$, the tangent of nominal slope angle of the pull curve tg*α*, the deformation work *A*, the complex hand parameter *Q* and flexibility parameter of fabric bending length *c*, improved significantly ascompared with those fabric samples washed without the softener. Most often the improvement exceeds the level of the measured parameters of the control specimen.

The specific reaction of the linen fabric LI-W with the softener could be related to the electric charge positive sign of the fabric surface and the wash out of the special finish materials.

The device KTU-Griff-Tester is suitable measurement device which enables to find the changes of mechanical properties of the woven and knitted fabrics after the washing, softening and other comparatively sensitive of keeping exploitation stability.

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