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The Change of Handle Properties of Knitted Fabrics Influenced by Washing Process

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The behavior of the knitted fabrics made from natural, man-made and synthetic fibers during washing process were tested. The stability of knitted fabrics was estimated according to the changes of friction coefficient values and handle parameters (defined by the KTU-Griff-Tester) after various modes of technological treatment. The relationship between friction coefficient and handle parameters and the fabric structure and the washing method was determined. The influence of the cationic chemical softener treatment on the stability of the handle parameters of the knitted fabrics is presented.
Keywords: textile, knitted fabric, friction, fabric hand, cationic softeners.

INTRODUCTION

At present various companies produce and distribute hundreds of chemical softeners for various types of the households. Usually, the materials with cation surface activation are used. They are liquid, easily dosed and do not become yellowish in color. When they are used during washing process the film occurs on the fiber surface which gives additional softness, smoothness and pleasant handle [1, 2].

The molecule of cationic softener in acid medium has slightly positive charge. Thus, the displacement of the softener on the surface depends on the fiber charge. Cellulose fibers have slightly negative charge therefore the cationic softeners with their hydrophilic charged part are directed to the fiber and with their water repellency part to the exterior. The overdosing of the softener should be avoided as the excess of the softener makes fabric too fatty.

In the previous work, devoted to the investigation of the change of the handle parameters of the textile fabrics, the washing process was shown as one of the worsening handle parameters. The reduction of intensity of the chemical softeners can make it slower [3].

The aim of this investigation was to define the regularity of the changes of friction and handle parameters of knitted fabrics. The influence of chemical softeners upon the stability of handle parameters was investigated.

MATERIALS AND METHODS

Five knitted fabrics made of natural (cotton (CO)), man-made (acetate CA), viscose (CV)) and synthetic (polyamide (PA), polyester (PES)) fibers were investigated (Table 1).

Experimental fabrics were prepared according to the following scheme. Five samples with the area of (40 cm × 50 cm) were cut from every fabric. Due to the samples pulling through the hole of the original KTU-Griff-Tester for each case of technological treatment, five samples were cut in the shape of disk (R = 56.5 mm). The technological treatment used was: washing and soaking in the solution of chemical softener. Automatic washing machine *Indesit* has been used for the washing. The temperature was programmed at T = 40 °C, for a duration for t = 60 min., with the washing powder *Ariel* (Czech Republic).

The cationic softener *Lenor* (Czech Republic) was used. Four sample groups of fabrics were used in the test: the first two groups were soaked in the same conditions in the water and chemical softener solution for 20 minutes. These samples were treated by the centrifuge and dried in horizontal position. The rest two were soaked after the washing had been accomplished.

The change and stability of the friction and handle parameters were judged in accordance with their changes of control specimen. The friction experiments were performed with a tensile machine Zwick/Z005 according to the DIN 53375, handle experiments were performed with an original device KTU-Griff-Tester. Two pads: glass and organic glass (same as used for the bearing plates of KTU-Griff-Tester) were used in the friction experiment. For each point 6 – 10 samples were tested. Such number of samples has always ensured the error level within the limits of 5 %.

The test regimes with KTU-Griff-Tester were chosen in accordance with the fabric thickness δ, estimating r conditions of the specimen jamming in the hole of the device, i.e. when r = 10 mm, $h = 5.6\,\delta/2$ [4, 5]. The handle of the test objects was estimated according to five parameters: (maximum extraction force $P_{\max}$, maximum deflection height $H_{\max}$, the tangent of nominal slope angle of the curve $\mathrm{tg}\alpha$, the deformation work A (the area under the curve) and the complex handle parameter Q), defined from the pull curve $H – P$ (deflection – power) and ($\Delta\delta$), according to the change of the sample thickness during the period of two loads [6 – 8].

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Table 1. Initial parameters of the investigated materials

Symbol of knitted fabric	Knitted fabric composition	Knitting structure	Wales per cm	Courses per cm	Area density, g/m^2	Thickness, mm
T11	100 % cotton (CO)	Rib 1×1 knitwear	P_h‘=11 P_h“=11	17	183	0.72
T12	96 % viscose (CV), 4 % elastane fibre (EL)	Plain jersey	5	30	248	0.64
T13	80 % acetate (CA), 20 % polyamide (PA)	Double jacquard	14	P_{vd}=5 P_{vk}=10	152	0.60
T14	100 % polyester (PES)	Warp-knitted locknit (cord-tricot)	14	14	142	0.49
T15	100 % polyamide (PA)	Brushed warp-knitted laid-in	24	20	179	0.99

RESULTS AND DISCUSSIONS

Table 2 shows that dynamic friction coefficient μ_D for organic glass is up to 32 % smaller comparing with glass. According to the all obtained results for the all technological treatment modes – $\mu_S < \mu_{OS}$. Exception is observed only for the fabric T13 (knitted fabric made out of acetate and polyamide fiber blend). In this case obtained results are opposite. The intensive increase of friction force is observed (see Fig. 1) when fabric T13 slips on the organic glass pad. This could be explained by the producing of charge and material interaction in a contact layer between two friction polymers of different origin. It is known, that electric charge accumulating on the polymer surface is able to increase friction forces up to tens of percents [9]. In case of fabric T13 this increase reaches 9 % – 25 %. The biggest difference between μ_S and μ_{OS} are obtained after SK and SK+L treatment, because washing process makes surface of the textile fabric rougher.

Friction experiment following the standard DIN 53375 and experiment of restricted pull through the hole showed, that high correlation exist between the dynamic friction force F_D and pull resistance parameters P_{max} and A. The best correlation (evaluated according to the value of r^2) and shape of a function is best in cases when the principal press force F_N is close to the pull resistance force P_{max}.

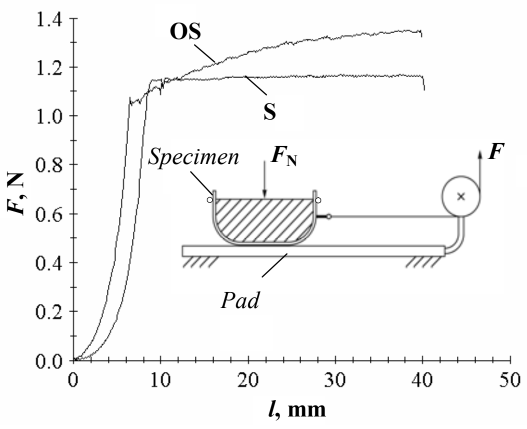

Fig. 1. Friction curves for fabric T13 to a glass surface (S) and organic glass surface (OS)

Both parameters P_{max} and A (Fig. 2) obey linear dependence $y = a + bx$ with F_D when $F_N = 7.03$ N ($r^2 = 0.9593 – 0.9844$). When F_N decreases till 1.97 N or increases up to 11.72 N, the shape of relationship becomes more complex and r^2 decreases. When $F_N = 21.53$ N function of the best relationship for both pads (S and OS) becomes complicated and $r^2 < 0.6$.

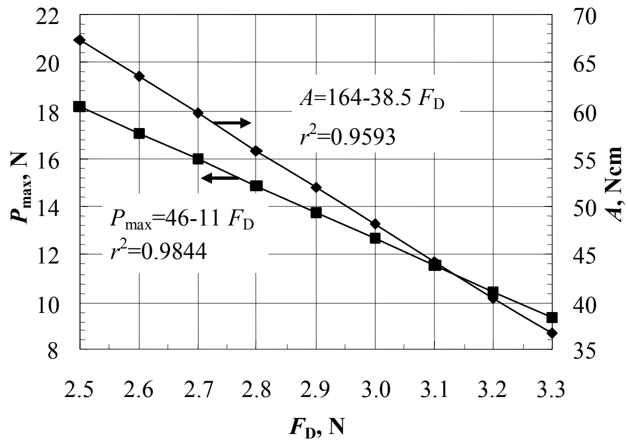

Fig. 2. The dependence of pull resistance parameters P_{max} and A of a specimen and dynamic friction F_D to a glass (when $F_N = 7.03$ N

Properly chosen conditions of a friction test, i.e. according to the parameter F_N, value can reliably predict the values of pull through the hole parameters P_{max} and A. In Fig. 3 the dependencies of technological treatment on the main handle parameters P_{max}, tgα, A and Q are presented. The analysis of the behaviour of knitted fabrics during washing shows, that the washing process makes the handle parameters worse. The amount of the chemical softener being in *Ariel* was unable to save handle parameters the same as for the control samples. Using supplementary chemical softener *Lenor*, the situation changes evidently during the rinsing process. The analysis of the six handle parameters revealed, that four main parameters of the handle P_{max}, tgα, A and Q, show maximum value for the all the tests after the washing (SK), and minimum value when the chemical softener *Lenor* (L) was used. The differences between these values are 1.4 – 2.4 times. For tgα it is 1.2 – 2.1 times and for A it is 1.5 – 2.3 times and for Q it is 3.1 – 26.0 times. The results indicate that the complex handle parameter Q is the most sensitive, because it in cludes not only parameters P_{max}, tgα and A, but also another two parameters $\Delta\delta$ and H_{max} reflecting fabric deformation characteristics. There is no regularity in the change of these parameters. Only for some fabrics some tendency was noticed when after washing and soaking $\Delta\delta$ and H_{max} values increased.

Table 2. The dependence of dynamic friction coefficient μ_D upon the modes of technological treatment

Symbol of knitted fabric	Dynamic friction coefficient μ_D									
	Technological treatment									
	K		W		SK		L		SK+L	
	Pad type									
	S	OS	S	OS	S	OS	S	OS	S	OS
T 11	0.46	0.39	0.46	0.38	0.44	0.41	0.46	0.41	0.45	0.48
T 12	0.43	0.40	0.45	0.37	0.49	0.35	0.49	0.37	0.53	0.35
T 13	0.61	0.67	0.57	0.70	0.51	0.68	0.59	0.75	0.49	0.80
T 14	0.37	0.29	0.38	0.27	0.36	0.29	0.36	0.25	0.37	0.26
T 15	0.40	0.36	0.41	0.39	0.43	0.41	0.43	0.40	0.47	0.42

Note: K – control, W – soaked in water, L – rinsed with *Lenor*, SK – washed, SK+L – washed and rinsed with *Lenor*; S – glass; OS – organic glass. Pad materials in a friction experiment were made of the same materials used for the bearing plates in a KTU–Griff–Tester

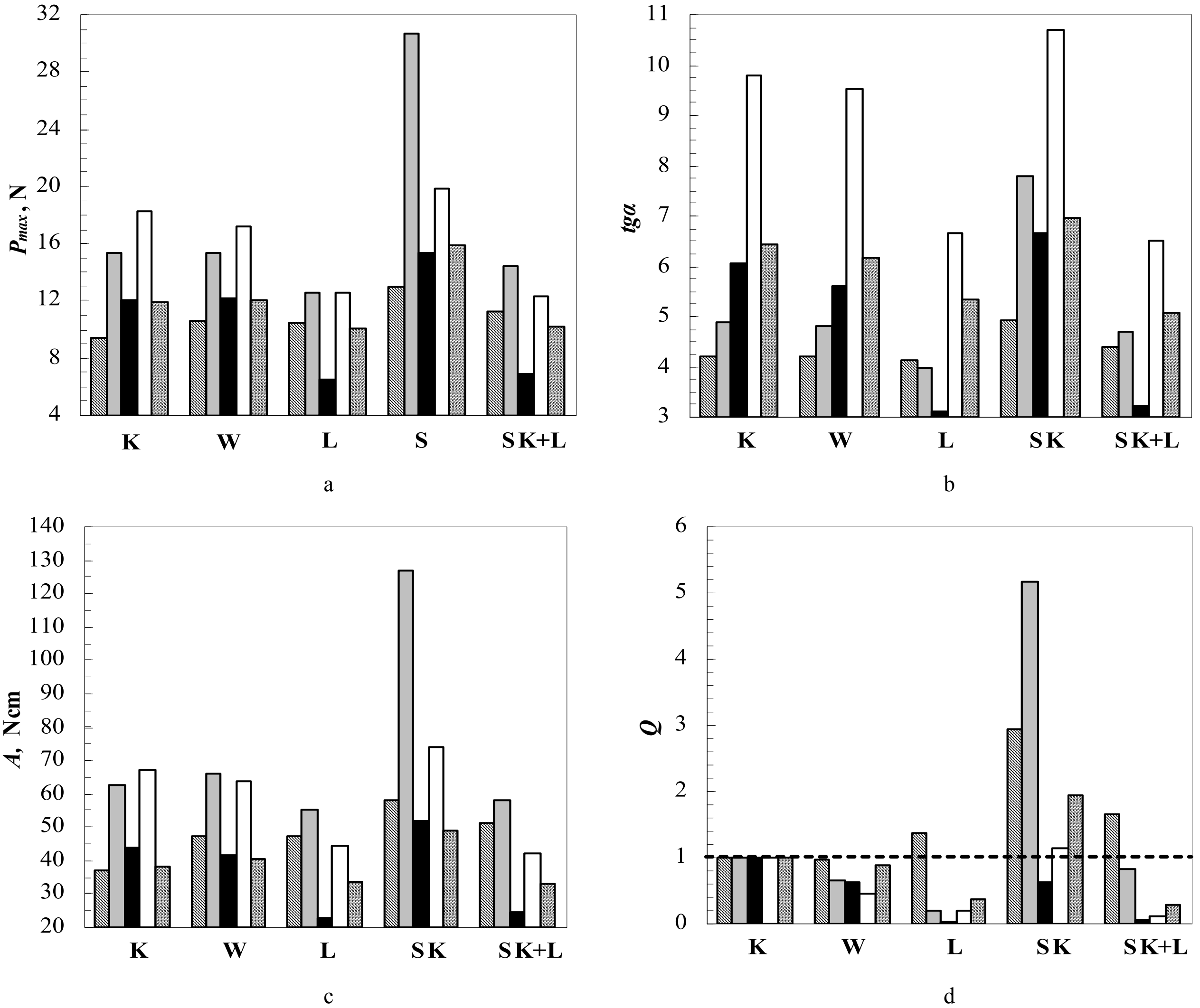

Fig. 3. The diagrams of the parameters P_{max} (a), tgα (b), A (c) and Q (d) during treatment of the test samples (-T11 -T12 -T13 -T14 -T15 , 1 Table)

The control of test sample thickness δ and mass m (Table 3) showed, that for the samples treated at various regime parameters δ varied in the range of 4.3 % – 18.7 %, and the parameter m changed in the range of 2.2 % – 19.0 %. The increase of thickness can be related to the degree of shrinking of fabric, and as it was expected it is the greatest after the washing. The mass m of samples and the change of volume density, which is related with it, in all cases, obtain the maximum value after the soaking in chemical softener. Supposedly, the samples put on some weight after the molecules of the softener have connected with the fibre.

It should be noted, that independently of the stage when the softener has been used, it has been always effective for the improvement of the handle parameters. The data (Fig. 3) show, that in spite of the fact the test samples were soaked in the medium of the softener before or after the washing, all the main parameters of the handle, practically remain the same. Thus, the original knitted fabrics after the final finishing operations contact with the

Table 3. Change limits (%) of the test sample thickness (δ), mass (m) and volume (μ)

Fabric symbol	δ, %	m, %	μ, %
T 11	18.7	19.0	1.2
T 12	9.4	9.9	4.9
T 13	9.9	3.5	10.3
T 14	4.3	2.2	2.5
T 15	6.4	3.0	5.0

chemical softener is the same, as one that received aggressive roughening impact during the washing.

The "sensitivity" of parameters to the action of the chemical softener depends on the fiber nature of the fabric. For example, after softening value of ΔP_{max} increases for viscose (T12) and acetate (T13) 2.4 times, for cotton (T11) about 1.4 times. Values of $\Delta tg\alpha$ change for acetate (T13) and viscose (T12) 2.1 and 2.0 times respectively, for cotton (T 11) and polyamide (T15) about 1.4 times. The variation of ΔA is 2.3 times for viscose (T12) and acetate (T13), and for polyamide (T15) and cotton (T11) 1.5 – 1.6 times. The results show increase of value ΔQ for viscose (T12) and acetate (T13) 26 for 25 times, for cotton (T11) and polyamide (T15) for 3.1 and 6.7 times, respectively.

It was surprisingly that fabric made of polyester (T14) was not presented in this comparison. It was thought that chemical softeners of cationic do not influence the polyester fabric. The values of obtained parameters were higher than the instrumental errors. According to the changes of the parameters δ, m and μ (Table 3), the fabric composition plays a crucial role here. Parameters δ, m and μ, as it should be expected change insignificantly. For the PES (T14) – 4.3; 2.2; 2.5 %, respectively. Fibers of PA (T15) are at the second position and having corresponding values: 6.4; 3.0; 5.0%.

As it can be seen from the data presented in the Table 3, the cellulose fiber shows the more significant changes of parameters δ, m and μ as compared a to ones for natural (cotton) and synthetic (polyester, polyamide) fiber.

The change of the handle parameters P_{max}, $tg\alpha$, A, H_{max} and Q is the most significant. Very similar differences (measured in relative units), were noticed for the viscose (T12) – (2.4-2-2.3-26) and acetate knitted fabric (T13) – (2.4-2.1-2.3-25). The smallest changes of these four parameters were noticed for the cotton (T11) – (1.4-1.2-1.6-3.1) and polyamide (T14) – (1.6-1.6-1.8-9.4) knitted wear.

The data show that the fabric T11 has been separated from the other cellulose type fabrics T12 and T13 and has occurred beside the polyester (T14) and polyamide (T15) fibres. Indistinctive place of the cotton fabric according to reaction with the cationic softener can be explained by the fibre shrinkage and the increased roughness and the stiffness of fabric.

CONCLUSIONS

It was found that chemical softener *Lenor* has positive effect on all tested objects, i.e. all types of knitted fabrics. Analysing the changes of all handle (P_{max}, $tg\alpha$, A, H_{max} and Q) parameters, the fabrics according to their sensitivity to the softener could be arranged in the following sequence: T12-T13-T14-T15-T11 (viscose (CV), acetate (CA), polyester (PES), polyamide (PA), cotton (CO)).

Soaking in the water fabrics of various compositions practically does not change the handle parameters (except Q). And the same soaking in the medium of cationic softener all the parameters (except for fabric T11) are radically improved.

The washing process worsens the handle properties significantly. The soaking of the washed samples in the softener regains the handle values to the level that was peculiar to the soaking in the softener before the washing. Besides, the effectiveness of the chemical softener remains the same despite of the stage when it was used – before or after the washing.

The investigation showed that the main handle parameters of all five investigated objects (after their treatment with *Lenor* softener) measured with KTU-Griff-Tester, have changed significantly. This testifies that the limited test method of the disc shaped specimen pulled through the circular hole is rather sensitive and enables to notice the changes of the fabric handle parameters even at soft regimes of technological treatment.

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