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Stress Relaxation of Clothing Fabrics and Their Systems

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The stress relaxation testing results of clothing fabrics and fussed systems (fabric or knitted fabric as main fashionable component and fussible interlining) are presented in the article. The tested specimens were quite different in physical characteristics, area density, weave, etc. Fussed systems are composed via fussing the main component with fussible interlining using the recommended regimes for these interlinings. The uniaxal tensile tests enabled to find that after the deformation of 15 % was reached (while testing the relaxation was stretched by 10, 15 and 20 %) the more significant stress part is being taken by fussible interlining, and its behaviour mostly influences the system‘s instantaneous elasticity as well as max stress value during the relaxation testing. While stretching the fussed systems till the breaking, at the first the less elastic fussible interlining is breaking, nevertheless its breaking point is approaching towards bigger extensions because of the fussible relations emerging during the fussing process. There was found the system stress relaxation is going in the same way as its components' relaxation: the most intensive stress change is having place at the beginning of the relaxation time the first 5 s – 20 s. After the deformation has been increased from 10 to 20 %, stress values F_{max} of a system and its components after the extension are going up, and the index of stress relaxation is changing depending on components‘ structure and physical characteristics.

Keywords: clothing fabrics, interlining, fused systems, stress relaxation.

INTRODUCTION

Most new generation fabrics are characterized as multifunctional, the tendency of joining different fabrics to one integral composition (system) is having place. Thus there is seeking to make the best fabrics' composition being characterized with necessary stability, elasticity, tensility, durability health and other important features. For the improving the clothes' wearing characteristics the fabrics are being fussed or putting together with interlinings, while composing the system with heterogeneous components: sometimes they significantly differ not only in raw material, structure, but also in mechanical characteristics [1, 2]. In such systems the main fashionable component ("the face") often is a woven or knitted fabric. After the fusing of main fabric and fusible interlining the mixed system is obtained, and its specific characteristics depend on main component, interlining as well as the interaction between them [3 – 5].

The applying of heterogeneous components in one item frequently increases mechanical stability of clothes' details (resistance to deformation in the forming process as well as shape saving after the forming) [3 – 7], the item shape constancy during the storing and wearing while it is under the small loading or deformations [8 – 10]. From this point of view the fabrics' behaviour is well defined by the relaxation processes [11 – 14], having place under the deformation or at the moment when the external forces have been taken away.

In case when the deformation and reological properties of separate components differ, there is very important to take into account the structure and relaxation features of each component (face component and interlining) as well as to define their influence for the behaviour of general system [13, 14].

The aim of this study is to investigate stress relaxation of different structure fabrics (suiting, knitted fabrics, adhesive bonded interlining) and fused systems as well as to find the influence of components' features for the long-term mechanical behaviour (relaxation) of general system.

EXPERIMENTAL

The fabrics of different structure were chosen for the research (fabrics A1, A2 and knitted fabric T1): they differ in physical features, i. e. raw material, strenght, area density, weaves type, etc. The fabric A1 is of plain weave, its warps and wefts are made from wool-corespun yarns and their core is one elastane thread (EL) (Table 1). Fabric A2 differs from the first one in weave, raw material (its warps and wefts are polyester threads (PES), bigger density of warps and wefts, thickness, as well as area structural characteristics.

Taking into account fast that the knitted fabrics' characteristics fundamentally differ from other fabrics because of their specific constitution and seeking to compare the behaviour of quite different fabrics, the rib jacquard suiting knitted fabric T1 was also investigated (Table 2). For the composition of fused systems the fusible interlinings K1 and K2 with the special warp-knitted fusible interlinings were investigated (Table 3). The wefts of interlining K1 are the wool threads, while the wefts of K2 – viscose yarns.

The specimens of separate fabrics as well as fused systems were investigated. Fused systems (fabric or knitted fabric as main component plus fusible interlining) were composed via fusing with the press under the recommended regimes for these interlinings (Table 3).

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Table 1. Structural characteristics of the face woven fabric

Fabric code	Fibre constitution	Yarn linear density, tex		Thickness, mm	Number of threads per dm		Area density, g/m^2	Weave
		warp	weft		warp	weft		
A1	Wool, EL	48	44	0.50	240	220	218	Plain
A2	PES	26	46	0.73	370	250	214	Derived twill

Table 2. Structural characteristics of the face-knitted fabric

Fabric code	Fibre constitution	Yarn linear density, tex		Stitch length, mm		Number of stitches per dm		Area density, g/m^2	Knitting structure
		right stitches	left stitches	right	left	wales	courses		
T1	Wool, PES	18	18	2.6	2.7	110× 2	280+110	306	Rib jacquard

Table 3. Structural characteristics of the warp-knitted fusible interlinings and fusing regimes

Fabric code	Fibre constitution	Structure	Inlay linear density, tex	Resin dots	Number of resin dots per cm^2	Area density, g/m^2	Fusing regime		
							Temperature, ^{0}C	Pressure, kPa	Time, s
K1	Wool, PES	Combined with weft inlay	26	PA	52	50	135	25	15
K2	CV, PA		39	PA	49	71	145	25	15

The tests were done using the tensile-testing machine with the equipment for the data registration in digital format [12].

Uniaxial tensile tests up to breaking were done according to the requirements of standard LST EN ISO 13934-1 (the gauge length was 100 mm, the specimens' width – 50 mm, initial tension – 2 N/5 cm, the tensile speed was 100 mm/min).

For the stress relaxation tests the gauge length was increased up to 220 mm, and the tensile speed – up to 550 mm/min. Other characteristics of these tests are as follows: the width of specimens is 50 mm, the initial specimens' tension is 2 N/5 cm, the specimens' deformation – 10, 15 and 20 % of starting gauge length, the duration of specimens deformation is from 2 s to 4 s, depending to the deformation degree, stress relaxation duration (the specimens under the deformation) – 1800 s. At a confidence level 96 % the confidence limits of the mean stress $F_{\max}$ and indices I_R were within the range to 7.8 % of the mean values.

RESULTS AND DISCUSSION

While defining the systems' break characteristics there was considered their breaking moment coinciding with the formerly breaking component's break point, which mostly is visible as fracture of curve, while for single components – in the top point of force-elongation curve. The average indices of stress-strain behaviour of investigated separate components and fused systems are presented in the Table 4, the typical cases force-elongation curves – in Figures 1 – 3.

Table 4. The average stress-strain behaviour indices of fabrics and fabric systems

Notation	Extension lengthwise				Extension crosswise			
	Breaking (maximum) force, N	Elongation at break, %	Initial modulus E_p, N/cm	Secant modulus E_m, N/cm	Breaking (maximum) force, N	Elongation at break, %	Initial modulus E_p, N/cm	Secant modulus E_m, N/cm
A1	582	68.8	0.1	0.9	551.8	63.3	0.1	1.6
A2	1102	66.1	–	–	1385	64.2	–	–
T1	422	113.2	0.1	0.4	431.7	144.7	0.1	0.5
K1	111	35.1	0.5	4.0	288.8	63.5	0.1	1.1
K2	138	37.5	0.2	2.4	104.7	18.2	0.4	6.2
A1+K1	613/422$^{\times}$	69.7/38.8$^{\times}$	0.3	4.9	932/929$^{\times}$	70.6/69.3$^{\times}$	0.2	2.0
A1+K2	576/446$^{\times}$	62.6/36.6$^{\times}$	0.4	4.7	607/160$^{\times}$	65.7/22.6$^{\times}$	0.3	6.6
A2+K1	1248/1051$^{\times}$	69.3/48.8$^{\times}$	–	–	1769/1563$^{\times}$	63.2/60.1$^{\times}$	–	–
A2+K2	1226/1185$^{\times}$	65.3/39.2$^{\times}$	–	–	1425/125$^{\times}$	67.2/17.7$^{\times}$	–	–
T1+K1	601/211$^{\times}$	138.7/48.4$^{\times}$	0.3	4.4	569/424$^{\times}$	156.1/64.9$^{\times}$	0.1	1.6
T1+K2	471/210$^{\times}$	125.3/39.5$^{\times}$	0.2	3.4	529/158$^{\times}$	163.7/19.7$^{\times}$	0.3	7.8

Notes: E_m – secant modulus (at 15 % elongation), $^{\times}$ – break of interlining.

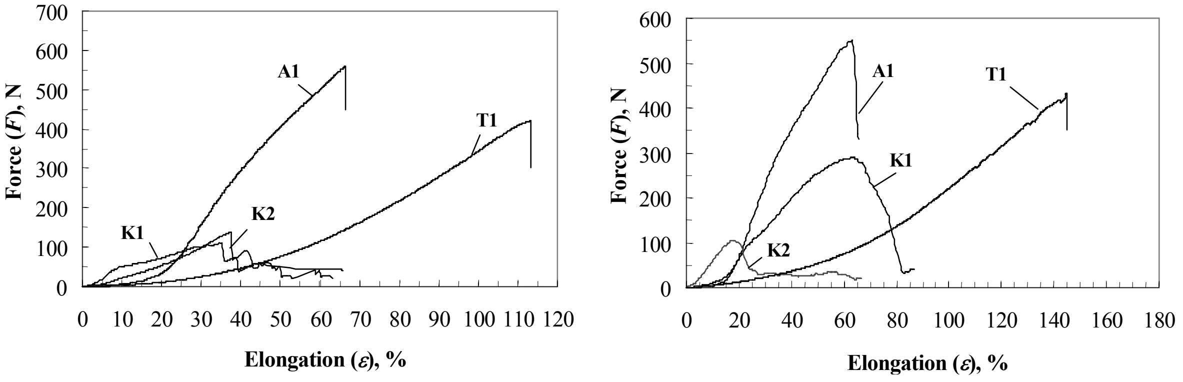

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Fig. 1. Force-elongation curves of components: a – extension lengthwise; b – extension crosswise

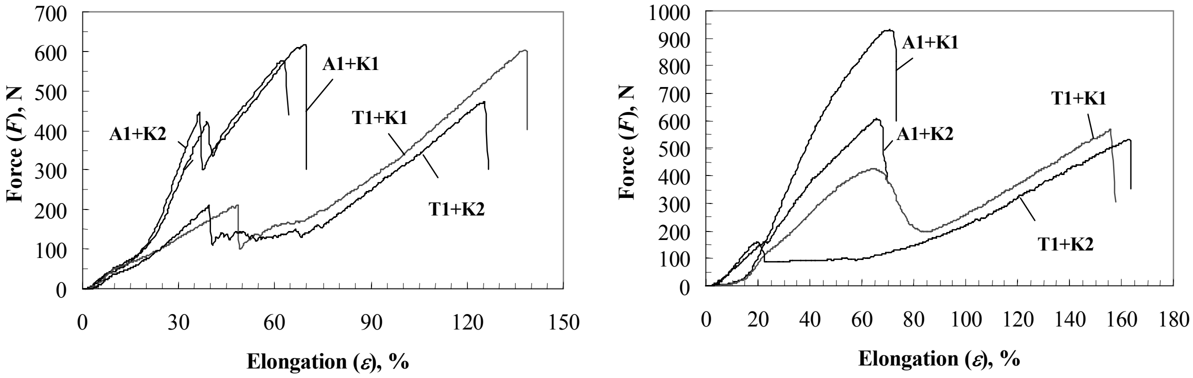

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Fig. 2. Force-elongation curves of fused systems: a – extension lengthwise; b – extension crosswise

The defined elongation of the fusible interlining is 2–3 times less than theirs' main components, but the elongation of interlining K1 in crosswise is close to the break elongation of fabrics A1 and A2 in the same direction. Furthermore, all the fusible interlinings characterized as having big anisotropy: the break elongation of K1 in crosswise is about twice bigger, and of K2 – twice less than in lengthwise.

This behaviour is conditioned mostly by characteristics of the wefts' yarns knitted into the structure of these interlinings.

The elongation values of main components A1 and A2 in both directions are very similar, nevertheless the break force of A2 is 2 – 2.4 times more than A1. The break force of knitted fabric T1 is close to dimension of A1, nevertheless it is about 3 times less than the break force of A2, and breaking elongation is 1.7 – 2.3 times more than fabrics' breaking elongation. This fact proves the break of any tested fabrics' systems "main component – interlining" during uniaxal tensile should start from the break of fusible interlining. This is confirmed also by systems' force-elongation curves (Fig. 2). These diagrams also demonstrate that because of new relations between the components during the fusing process the breaking moment of less tensile element approach towards the bigger elongation and therefore the breaking force is increased.

Taking into account fact that the textile fabrics are able to resist the tensile and other forces of long and short duration, the intensity of stress and creep recovery mostly depends on raw material, fabric or knitted fabric as well as the structure of composing threads. Therefore, at first the rigidity of investigated fabrics was defined according to the initial and secant elasticity module. There was stated the initial E_p and secant E_m elasticity module values of the fusible interlining K1 in lengthwise and K2 in crosswise are of several times more than other investigated fabrics. Therefore, the secant modulus values of systems with this component in starting tensile stage are influenced not by main component, but by the interlining (Table 4).

The same result could be confirmed on the basis of the maximal stress values $F_{\max}$ of systems and theirs components defined after the tests of stress relaxation. For example, fusible interlining K1 and K2 in lengthwise is 8.6 N/cm and 6.4 N/cm, and systems A1+K1, A1+K2 is 9.4 N/cm and 7.5 N/cm; respectively in crosswise – 1.3 N/cm and 16.5 N/cm as well as systems' – 1.9 N/cm and 18.4 N/cm (Figs. 3 and 4, Table 5).

While the specimens' tensile extent has been increased, the influence of interlining for the system's stress $F_{\max}$ value is going down: as the constant deformation was increased twice (from 10 % to 20 %, $\Delta\varepsilon_{t^*} = 5$ %) the $F_{\max}$ of main component is increased from 2.7 to 7.5 times, and the stress of fusible interlining – up to 2 times. Exception – the interlining K1 in crosswise, its stress is increased up to 8.2 times and equal the stress increasing degree of main components. Therefore, the stress of systems, made with this interlining in crosswise and stretched by 20 %, is up to 8 times greater than for the systems, which are twice less stretched.

To define the deformation influence on the stress relaxation, the specimens were stretched by 10, 15 and 20 %. The quantifiable estimation of stress relaxation was done using the relaxation indices I_R (%), defining the change of stress in a certain time period and comparing it with the start-up value. Stress relaxation was estimated using relaxation indices I_R (Table 5) or change of the relaxation indices ΔI_R during the first 18 s and during the period from 18 to 1800 s from the stretching start-up.

On the basis of these results there was considered the average stress change intensity of different fabrics and systems at the first (till 18 s) and the second stages (till 1800 s) of relaxation process. There was found the relaxation process of fabrics A1 and A2 on the start-up stage in most cases is less intensive than knitted fabrics‘ (main component T1 and interlinings‘ K1, K2), for example while the specimens were stretched by 15 %, the fabrics‘ values ΔI_R after 18 s were reaching 11 – 15 %, and knitted fabrics‘ is from 18 % to 27 %.

There was found the stress relaxation process of fabrics A1 and A2 on the start-up stage in most cases is less intensive than for knitted fabrics‘ (main component T1 and interlinings‘ K1, K2), for example while the specimens were stretched by 15 %, the fabrics‘ values ΔI_R after 18 s were reaching 11 % – 15 %, and knitted fabrics‘– from 18 % to 27 %.

The same stress change tendency remains in the interval from 18 s to 1800 s – the fabrics‘ΔI_R = 9 % – 16 %, and knitted fabrics‘ – 11 % – 31 % (exception is knitted fabric T1 in crosswise, its ΔI_R = 5 %, i.e. about twice less than fabrics‘). This proves that the elasticity characteristics of tested fabrics are more asserted comparing to the interlinings or lengthwise knitted fabric T1. After fussing with interlinings the differences of systems’ relaxation behaviour in practice disappeared. Nevertheless both on

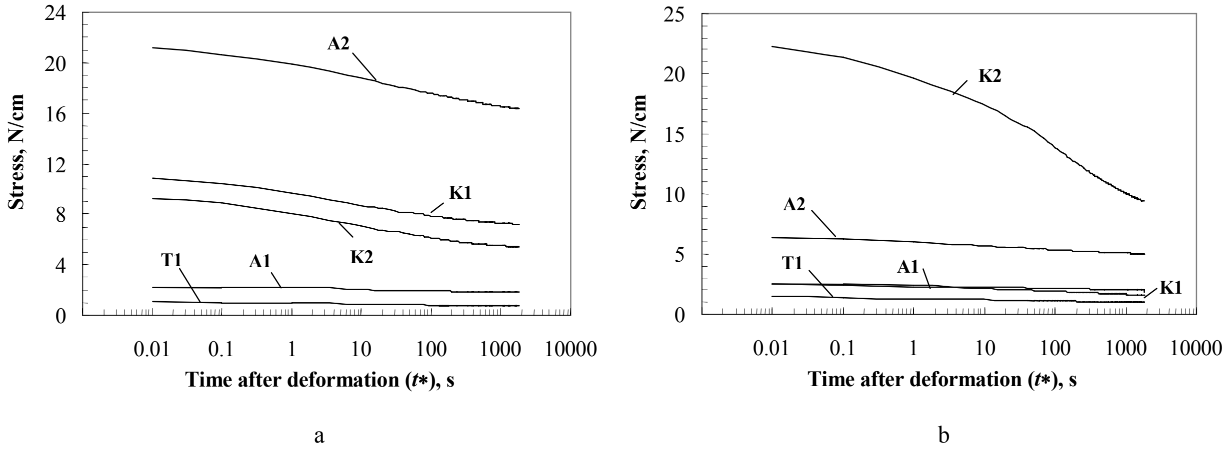
Table 5. The stress relaxation indices of clothing fabrics and their systems

Notation	ε_{t*}, %	$F_{\max}$, N/cm	Relaxation indices I_R, %			$F_{\max}$, N/cm	Relaxation indices I_R, %		
			18 s	180 s	1800 s		18 s	180 s	1800 s
A1	10	1.2	97	93	85	1.5	92	90	87
	15	2.3	88	84	72	2.7	89	85	80
	20	6.8	85	80	75	9.0	86	83	70
A2	10	6.7	92	80	76	2.4	94	90	80
	15	21.3	85	80	75	6.5	87	81	77
	20	50.2	78	73	68	14.7	83	78	75
T1	10	0.4	89	80	79	0.8	74	64	53
	15	1.1	81	71	70	1.5	75	71	70
	20	1.6	76	68	66	2.2	90	87	86
K1	10	8.6	82	73	71	1.3	70	59	47
	15	11.8	76	68	64	2.7	82	74	62
	20	13.6	77	72	69	10.7	74	68	65
K2	10	6.4	73	63	52	16.5	74	64	53
	15	9.9	73	64	58	22.3	73	57	42
	20	12.0	77	69	64	–	–	–	–
A1+K1	10	9.4	81	74	68	1.9	89	83	74
	15	12.8	78	73	67	4.4	87	79	73
	20	17.9	77	71	66	13.0	83	76	72
A1+K2	10	7.5	68	57	49	18.4	72	62	55
	15	11.8	77	68	63	29.5	70	60	54
	20	16.4	79	70	64	–	–	–	–
A2+K1	10	16.2	85	79	73	2.8	91	84	75
	15	23.9	82	75	70	6.9	84	77	71
	20	53.1	79	73	69	18.5	82	75	70
A2+K2	10	12.5	78	68	62	18.0	72	61	53
	15	22.5	80	72	66	27.3	74	63	56
	20	52.2	82	75	71	–	–	–	–
T1+K1	10	8.9	76	68	63	1.6	71	61	53
	15	12.1	77	69	65	3.5	79	73	67
	20	15.2	78	71	68	12.5	78	70	66
T1+K2	10	7.2	70	58	47	24.7	72	62	53
	15	10.4	73	64	58	35.6	65	58	51
	20	13.1	78	72	68	–	–	–	–
In vertical direction						In transverse direction			

the start-up stage and later the relaxation index's ΔI_R values of all systems with interlining K2 were bigger by 1-4 % in lengthwise, and by 2 % – 7 % in crosswise.

When the relaxation indices'ΔI_R values of interlinings are 1.5 – 5 times bigger than the main component, after fussing the interlining has more significant influence on systems' relaxation intensity. When these values of both components are similar, the system's relaxation is the same as for its main component.

The intensity of specimens' stress relaxation is influenced by their deformation size as well: in most cases after the specimens' deformation was increased from 10 % to 20 % the stress relaxation change values ΔI_R of separate components and systems both on the start-up stage and



a b

Fig. 3. Stress relaxation of components in lengthwise (a) and crosswise (b), when the deformation $\varepsilon_{t*} = 15$ %

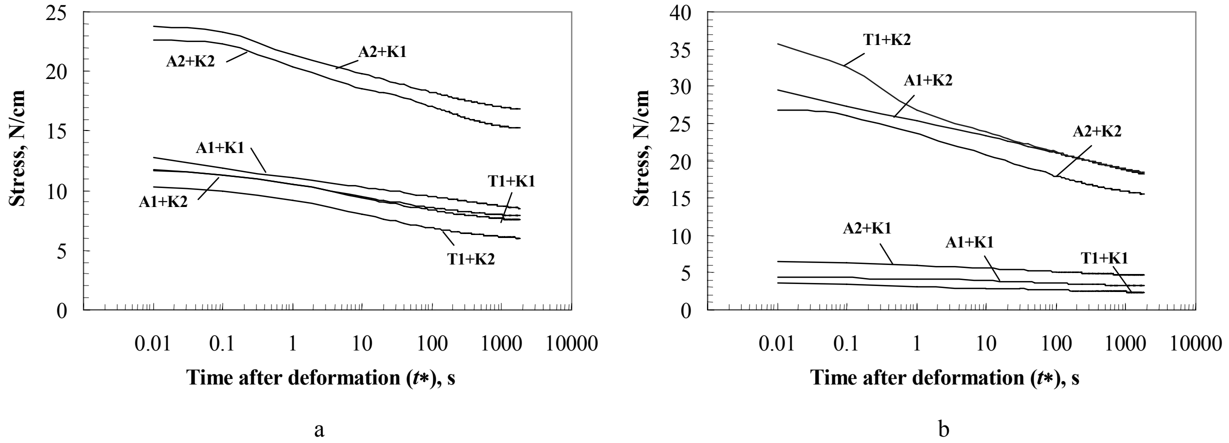


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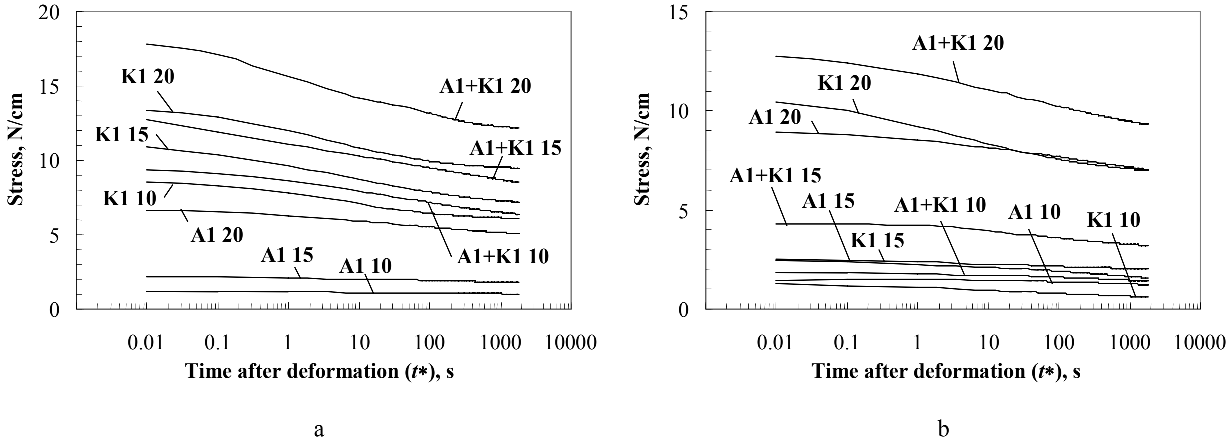
Fig. 4. Stress relaxation of the fused systems' in lengthwise (a) and crosswise (b), when the deformation $\varepsilon_{t*} = 15$ %



a b

Fig. 5. Stress relaxation of components (A1, K1) and their systems in lengthwise (a) and crosswise (b), when the deformation ε_{t*} is different (10 %, 15 %, 20 %)

later decreased up to 13 % (Fig. 5). The behaviour of interlining K2 and together with it composed system in lengthwise as well as behaviour of knitted fabric T1 and together with it composed system in crosswise is quite different (ΔI_R is increasing up to 16 %), nevertheless for the explanation of these differences further special investigations are necessary.

CONCLUSIONS

1. The elasticity module values of systems, composed from fabric or knitted fabric as main component and interlinings, on the start-up stretching stage ($\varepsilon_{t*} = 15$ %) are determined by the tested interlinings.
2. While the stretching extent has been increased from 10 to 20 %, the stress of the systems and their components increase up to 8 times. The specimens' deformation size influences the intensity of stress relaxation; nevertheless the obtained results are not homologous.
3. The stress relaxation of fabrics on the start-up stage (up to 18 s) and later is less intensive than the knitted fabric's T1 stress relaxation and interlinings (except T1 in transverse direction) because of more characterized elasticity properties of the tested fabrics.
4. When the relaxation indices' ΔI_R values of interlinings are 1.5 – 5 times greater than over of the main component, after fussing the interlining has more significant influence on systems‘ relaxation intensity. When these values of both components are similar, the system‘s relaxation is the same as for its main component.

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