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Influence of Hygrothermal Treatment on the Stress Relaxation of Clothing Fabrics' Systems

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The experimental results of stress relaxation under the conditions of hygrothermal treatment of clothing fabrics and fused systems (fabric as a main component and fusible interlining) are presented. The hygrothermal treatment of specimens was carried out while applying three steaming cycle types: when steaming was carried out before the stretching, during stretching and after it. The stress value F_{max} of the system and its component was obtained to be dependent not only on the specimens' stretching degree, but also on the chosen steaming cycle type. The smallest resistance to the stretching was obtained when the steaming was carried out during the stretching. While applying this type of steaming, the most specimens' values of the relaxation indexes I_{10} and I_{180} are respectively up to 10 % and up to 20 % bigger than the non-steamed specimens'. This proves the decrease of the stress change intensity after the stretching and very intensive stress relaxation during the stretching-steaming process. After increasing the stretching degree, the maximum stress value, residual stress and relaxation intensity of the textile fabrics ant their systems increased, and change of the stress F_{max} after the hygrothermal treatment slightly decreased.

Keywords: hygrothermal treatment, fabrics, interlining, fused systems, stress relaxation

INTRODUCTION

Seeking to increase the outerwear's dimensional shape stability, obtained during the manufacturing process, and assuring its long-term retention, the parts of upper fabric are being fused with fusible interlinings [1 – 4]. The optimal combination of fabrics (heterogeneous system) is used, obtaining the characteristics such as strength, elasticity, extensibility, durability relaxing and other important characteristics. Very frequently use of heterogeneous components in one product not only increases the mechanical stability of clothing parts [5, 6], but also increases the shape stability during the production process, storage and wearing, while the clothing item is under the small loadings or deformations [7, 8].

Long-term retention of dimensional clothing shape stability is guaranteed not only by applying of fusible interlining, but also by the various thermal – humidity processes, carried out in the process of production. During these processes the fabrics and clothing parts are being shaped or stretched, the clothing shaping is carrying out under the conditions of hot steams, that enables to reach the high processing quality of clothing [9, 10]. Under the treatment of humidity the stress relaxation of stretched fabrics and their systems takes place [11, 12].

When the deformation and rheological properties of separate components in fused system differ, the fabrics under the humidity treatment differently absorbe water steam, they differently swell and their structure is changing differently.

The aim of this study is to investigate the stress relaxation of fabrics' systems and their components, having place under the hygrothermal treatment or after it.

EXPERIMENTAL

The suiting face woven fabric A and fused systems A/I1, A/I2 in this study were investigated. The structural characteristics of fabrics are presented in the Table 1, and the characteristics of fusible interlinings – in the Table 2. Before the tests all the specimens have been conditioned for 24 hours (T = 23 ±2 °C, φ = 50 ±5 %). The stress relaxation tests were carried out using the computerized tensile-testing machine [5] including additionally installed equipment of specimens' steaming (Fig. 1) meeting the following conditions: the gauge length was 250 mm, the specimens' width – 50 mm, the initial tension – 0.1 N/cm, the tensile speed – 200 mm/min, all the testing time t = 180 s, steam pressure – 0.2 MPa, the distance between steam spreader and the specimen – 5 mm, the steam temperature on the specimen surface T_g = 75 ±5 °C.

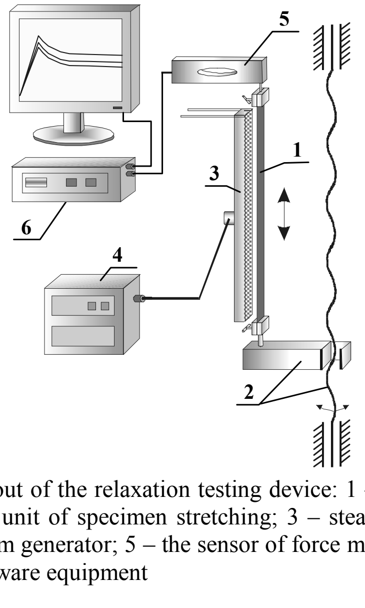

Fig. 1. The layout of the relaxation testing device: 1 – specimen; 2 – the unit of specimen stretching; 3 – steam spreader; 4 – steam generator; 5 – the sensor of force measurement; 6 – software equipment

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Table 1. Structural characteristics of the face woven fabric

Code	Fibre constitution	Yarn linear density, tex		Number of threads per dm		Area density, g/m^2	Weave
		warp	weft	warp	weft		
A	45 % Wool, 55 % PES	36	36	300	220	277	Twill 2/1

Table 2. Structural characteristics of the fusible interlinings

Code	Fibre constitution	Structure	Resin dots	Area density, g/m^2	Number of resin dots per cm^2
I1	PES	Fabric (Twill 2/2)	PA	90	49
I2	Wool, PES	Warp knitted fabric	PA	50	52

The fused system is steamed from the main face of fabric. At a confidence level 95 % the confidence limits of the mean stress $F_{\max}$ and indexes I_R were within the range to 7.8 % of the mean values. The specimens' stretching degree was 40 % of breaking elongation of the used interlinings ($\varepsilon = 0.4\varepsilon_{\text{break}}$), i. e. 9 % (A, A/I1) and 14 % (A, A/I2) lengthwise and respectively 8 % and 6 % for crosswise. The specimens' hygrothermal treatment was carried out applying three steaming cycle types (Fig. 2):

1. The steaming cycle finish coincides with the specimen stretching start and the duration of steaming is $\theta_1 = 10$ s.
2. The duration of steaming θ_2 is equal to the specimen deformation duration and the steaming cycle finish coincides with the stress relaxation initial point.
3. The steaming starts in 5 s after the specimen stretching and the duration of steaming is $\theta_3 = 10$ s. The agreed relaxation initial point coincides with the steaming cycle start.

RESULTS AND DISCUSSION

The testing results of the control specimens and specimens, treated by steam, were compared. The hygrothermal treatment on the stress relaxation of fabric (A) and fused systems (A/I1 and A/I2) in the uniaxial stretching case was defined (Tables 3 – 6).

The maximum stress $F_{\max}$ of the treated by steam specimens (on the first and the second steaming stage) on the initial point of relaxation process was obtained. It is up to 1.7 times less (Fig. 3, c – f) than that for untreated (Fig. 3, a and b).

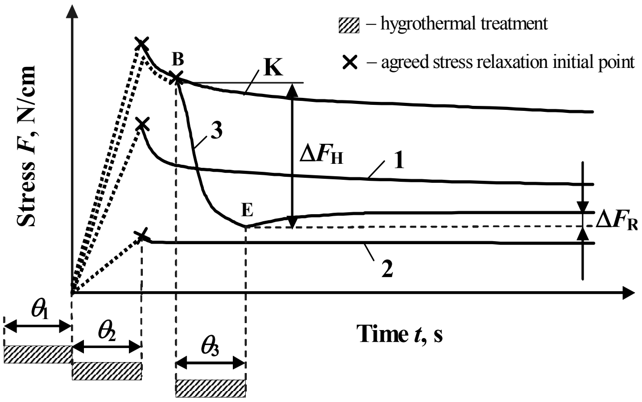


Fig. 2. Schematic layout of the stress relaxation process, when the specimens are being stressed after the hygrothermal treatment (1), under the treatment of steam during the stretching time (2) and respectively after the stretching (3); K – control relaxation curve of the (dry) specimens; ΔF_H – data of relaxation; ΔF_R – data of inverse relaxation

Table 3. The stress relaxation data of interlining I1, fabric A and system A/I1 (∧ – lengthwise $\varepsilon = 9$ %, > – crosswise $\varepsilon = 8$ %)

Notation	Direction	$F_{\max}$, N/cm	Residual stress, N/cm	Relaxation indices I_R, %	
				I_{10}	I_{180}
Test of control specimens					
I1	^	17.7	13.7	85.8	77.3
	>	2.0	1.7	90.0	85.7
A	^	57.8	45.8	87.8	79.2
	>	17.4	14.9	91.4	85.9
A/I1	^	69.1	54.5	87.1	79.0
	>	18.7	15.8	91.4	81.7
Test, applying 1 steaming cycle					
I1	^	14.5	11.2	83.4	77.2
	>	1.7	1.5	94.1	88.2
A	^	43.8	35.1	86.3	79.9
	>	12.3	10.2	88.6	82.9
A/I1	^	44.6	34.7	85.6	77.8
	>	12.4	10.3	88.7	83.0
Test, applying 2 steaming cycle					
I1	^	7.9	7.7	93.7	97.5
	>	0.7	0.7	85.7	99.9
A	^	27.5	24.9	90.5	90.5
	>	7.1	6.9	97.2	97.2
A/I1	^	27.6	24.5	89.1	88.7
	>	7.8	6.7	85.8	85.9

Table 4. The stress relaxation data of interlining I1, fabric A and system A/I1 (applying 3 steaming cycle)

Notation	Direction	$F_{\max}$, N/cm	F_B, N/cm	F_E, N/cm	ΔF_H, N/cm	Relaxation indices I_R, %		ΔF_R, N/cm	Residual stress, N/cm
						I_1	I_5		
I1	^	17.3	13.8	5.2	8.6	73.9	42.0	0.6	5.8
	>	2.1	1.6	0.2	1.4	68.7	25.0	0	0.2
A	^	57.4	49.2	18.2	31.0	76.6	42.7	1.7	19.9
	>	18.2	15.7	5.3	10.4	96.8	54.4	1.0	6.3
A/I1	^	68.7	55.9	27.0	28.9	89.8	55.8	2.1	29.1
	>	17.1	15.8	5.8	10.0	99.3	49.8	0.1	5.9

Notes: F_B – the stress, defined in the steaming process beginning; F_E – the stress, defined in the steaming process end (Fig. 2).

When the specimens were steamed before the stretching, $F_{\max}$ decreased up to 36 % lengthwise and up to 48 % crosswise. While the specimens were steamed during the stretching, the stress decreased up to 60 % and 65 % respectively.

When dry specimens were stretched and their steaming was carried out after the relaxation process started, the stress from the initial value in 10 s decreased to 48 % lengthwise and to 37 % crosswise (Table 4 and Table 6). The initial stress value in this case is defined on the point, where the steaming process is started, i. e. at 5 s from the stretching.

The changes of stress maximum values show that the resistance to stretching force volume having place during products' shaping essentially depends on the steaming cycle type. The least resistance is obtained when the steaming is carried out in the stretching process. Furthermore in this case the shortest product shaping process is possible.

After comparing the initial stress values of stretched by different degree specimens there is obvious that the steaming of more strained specimens has less influence on the stress changes.

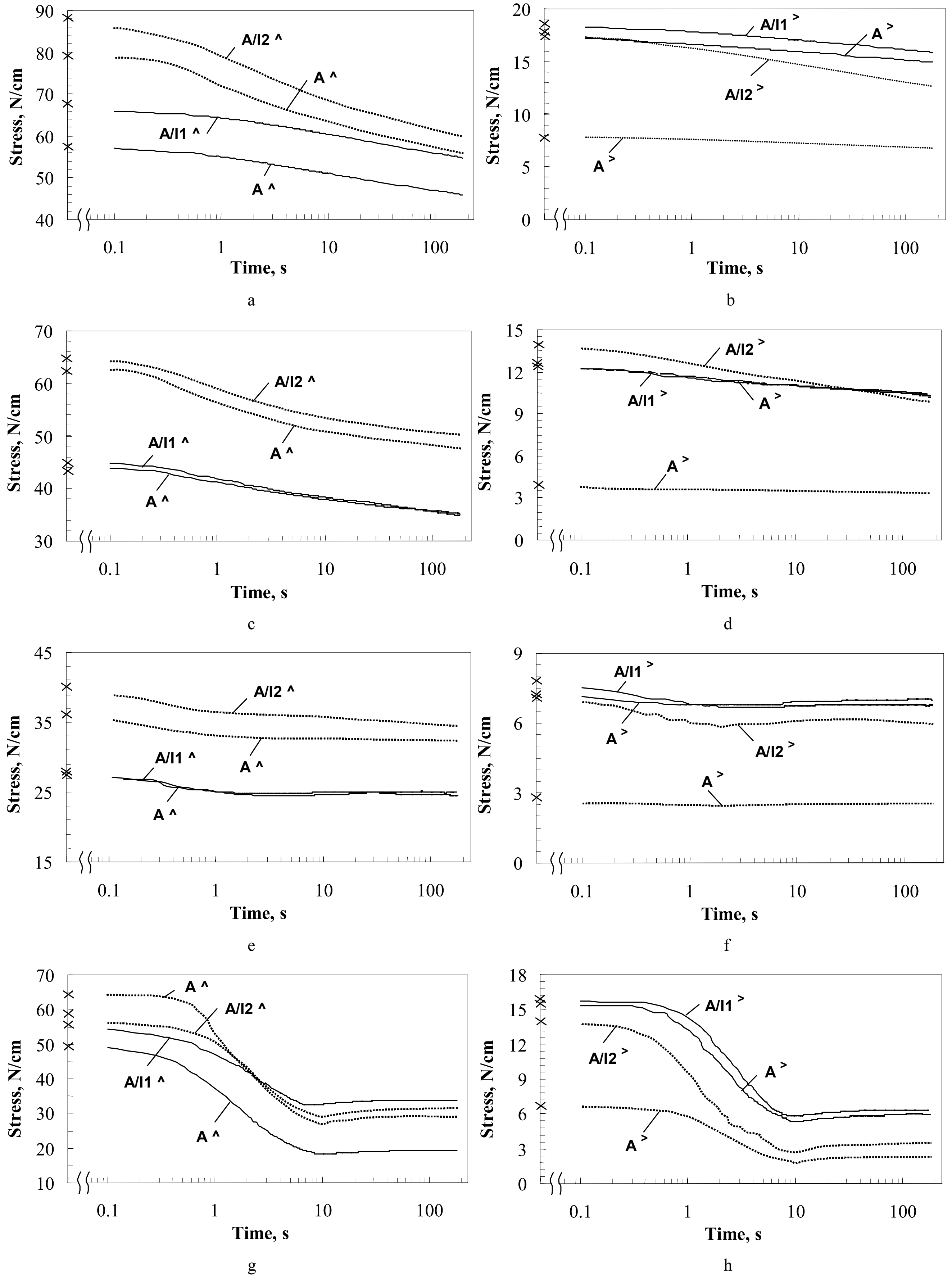
Table 5. The stress relaxation data of interlining I2, fabric A and system A/I2 (∧ – lengthwise $\varepsilon = 14$ %, > – crosswise $\varepsilon = 6$ %)

Notation	Direction	$F_{\max}$, N/cm	Residual stress, N/cm	Relaxation indices I_R, %	
				I_{10}	I_{180}
Test of control specimens					
I2	^	11.0	7.9	80.0	70.9
	>	9.5	6.7	82.1	69.5
A	^	79.4	55.6	79.4	70.0
	>	7.8	6.7	91.0	85.9
A/I2	^	85.7	59.7	79.7	69.6
	>	17.6	12.5	82.9	71.0
Test, applying 1 steaming cycle					
I2	^	9.6	7.3	81.2	76.0
	>	8.6	5.1	77.9	59.3
A	^	62.7	47.5	81.0	75.7
	>	3.8	3.4	92.1	89.5
A/I2	^	64.4	50.1	82.7	77.6
	>	13.9	9.8	81.3	69.7
Test, applying 2 steaming cycle					
I2	^	6.6	5.6	89.4	84.8
	>	3.8	2.4	78.9	64.0
A	^	36.4	32.2	89.8	88.7
	>	2.8	2.4	89.3	85.7
A/I2	^	40.4	34.3	88.4	85.2
	>	7.2	5.9	84.7	82.0

Table 6. The stress relaxation data of interlining I2, fabric A and system A/I2 (applying 3 steaming cycle)

Notation	Direction	$F_{\max}$, N/cm	F_B, N/cm	F_E, N/cm	ΔF_H, N/cm	Relaxation indices I_R, %		ΔF_R, N/cm	Residual stress, N/cm
						I_1	I_5		
I2	^	11.2	7.9	5.0	2.9	91.8	67.0	0	5.0
	>	9.4	6.9	0.1	6.8	37.6	2.3	0.5	0.6
A	^	79.2	63.2	29.2	34.0	75.8	50.2	1.1	30.3
	>	7.6	6.6	1.9	4.7	86.3	37.9	0.2	2.1
A/I2	^	85.4	68.2	32.3	35.9	87.2	54.2	1.5	33.8
	>	17.5	13.9	2.7	11.2	69.0	27.3	0.7	3.4

Notes: F_B – the stress, defined in the steaming process beginning; F_E – the stress, defined in the steaming process end (Fig. 2).



a

b

c

d

e

f

g

h

Fig. 3. Stress relaxation of fabric A and fused systems A/I1 and A/I2 (a, b) and when the specimens are being stretched after hygrothermal treatment (c, d); when specimens are being steaming during the stretching process (e, f); when specimens are being steaming after the stretching process (g, h): ^ – lengthwise; > – crosswise; ——— – when lengthwise $\varepsilon = 9$ %, crosswise $\varepsilon = 8$ %; ············ – when lengthwise $\varepsilon = 14$ %; crosswise $\varepsilon = 6$ %; × – initial stress value

For example, the initial stress $F_{\max}$ of control fabric's A specimens in lengthwise, when the extension 9 % and 14 % corresponds to 58 N/cm and 79 N/cm, steamed by the first type – 44 N/cm and 63 N/cm (decrease 24 % and 20 %), and steamed by the second type – 27 N/cm and 36 N/cm respectively (decrease 54 % and 52 %) (Tables 3 and Table 5). The same trend is obvious in the case of other specimens' testing and the third steaming cycle (Fig. 3).

The stress relaxation was quantitatively estimated using the relaxation index I_R (%) [12] that indicates the stress change after 10 s (I_{10}) and 180 s (I_{180}) (the time, applied for the specimens, which were steamed after the stretching, was 1 and 5 seconds). The testing results were compared for the non-steamed and steamed specimens.

The relaxation index I_R of steamed before stretching system A/I1 and its components A, I1 both in lengthwise (when $\varepsilon = 9$ %) and crosswise (when $\varepsilon = 8$ %) was obtained to be from 1.2 % to 3.5 % less than that for dry specimens. The relaxation index values of system A/I2 with knitted fusible interlining I2 were found to be from 4 % to 8 % higher. One can assume that such a behavior of system A/I2 is mostly influenced by the interlining I2 structure and its elastic characteristics [2, 4, 10, 13, 14]: the interlining is warp-knitted fabric combined with weft inlay. While applying the second steaming cycle version, the relaxation index I_{10} values of most specimens are bigger up to 10 % and I_{180} – up to 20 % bigger than that for dry specimens. This difference of index I_R values shows the intensive decrease of the stress change after the stretching and obviously rather intensive stress relaxation during specimen's stretching-steaming process (Fig. 3, e, f).

Significant intensity of the stress change (relaxation) during the steaming are confirmed and clearly demonstrated by the results obtained in the process of steaming the specimens, which were stretched before (the third steaming cycle) (Fig. 3, g, h): the index I_1 of system A/I1 and its components is less up to 18 %, and I_5 is less even up to 65 % than dry specimens (Table 4), and the index I_1 of system A/I2 with warp-knitted fusible interlining – respectively less up to 53 %, and I_5 – up to 82 % (Table 6). In 10 s – 12 s after hygrothermal treatment, when specimens' and environment temperature is equalizing. When the part of over humidity leaves the specimens, the stress values start to slightly increase. The inverse (stress) relaxation in the size of ΔF_R is settling in 90 s – 120 s after the test start, the stress values remain constant till the test end (Fig. 3, g, h).

After the increase of stretching extent, the values of the stress relaxation indices slightly decreased in all applied steaming cycles (the relaxation intensity increased): for example, index I_R of non-steamed lengthwise fabric A slightly decreased approximately by 9 %, the index I_R decrease of the steamed before the stretching specimens reaches 5 %. While index I_R decrease of specimens, steamed in the stretching process or after the stretching is only about 1 %.

While comparing the control and treated by steams specimens' residual stress values, we found the following: while applying the first steaming cycle the residual stress of system A/I1 and its components A decreased up to 36 %, and for system A/I2 – up to 48 %. Applying the second steaming cycle the obtained results show, the residual stress of system A/I1 and its components decreased up to 57 %, and of system A/I2 as well as its components – up to 64 %. Nevertheless the most significantly decreased the values of residual stress (up to 90 %) when the hygrothermal treatment was applied after the specimen's stretching (in the third steaming cycle types).

While increasing the stretching deformation, not only initial but also the residual stress is increasing. The results of this experiment are confirmed by the results of previous studies [7, 12]. After all it was found the residual stress change of steamed specimens in all cases is increasing because of bigger stretching, comparing to the respective change of dry specimens. For example, the residual stress of fabric A is increasing from 18 % of dry specimens up to 34 % of steamed after stretching.

CONCLUSIONS

1. The stress values and relaxation behavior of textile fabrics and fused systems during uniaxial stretching and hygrothermal treatment depend on the steaming cycle, specimens' deformation degree: the smallest maximal stress values are obtained, when the steaming process is carried out during the specimens' stretching (comparing to the control specimens, stress $F_{\max}$ is decreasing up to 65 %), and the change of these stresses because of bigger specimens‘ extension is slightly decreasing (up to 2 %).
2. The significant increase of relaxation index‘s I_R values (up to 20 %) during the steaming in the process of specimens' stretching indicates the decrease of the stress change intensity after stretching and very intensive stress relaxation during stretching-steaming process, what is also confirmed by the results (I_R values of some specimens decreased even up to 85 %) obtained during steaming the specimens, which were stretched before.
3. The biggest decrease of residual stress value was obtained while the hygrothermal treatment was carried out after specimen‘s stretching (up to 90 %) and while steaming in the process of stretching (about 60 %).

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