The analysis of dimensional stability of 1x1 RIB CO and CO/LY knitwear

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REZUMAT – ABSTRACT

Analiza stabilității dimensionale a tricoturilor patent 1x1 CO și CO/LY

Această lucrare analizează impactul compoziției fibroase, a densității liniare și finisajului firelor asupra stabilității dimensionale a tricotului patent 1x1 realizat pe mașina de tricotat circulară. Stabilitatea dimensională a fost analizată prin metoda FAST 4. Diferite probe au fost comparate prin intermediul mai multor indicatori. Rezultatele arată că cea mai stabilă variantă tricotată, vopsită este din: 96% CO / 4% Lycra și fire cu densitate liniară 19,14 tex. Valorile factorului de etanșeitate în stare uscată de relaxare s-au situat la 17,90, în cea umedă la 18,45, în total 18,73 și 18,59 în condiții de climatizare standard. Tricoturile cu cele mai ridicate valori ale instabilității dimensionale sunt tricoturile crude din 100% CO și fire cu densitate liniară de 13,39 tex. Valoarea factorului de etanșeitate în stare uscată de relaxarea a fost de 12,16, în cea umedă la 12,36, în total 13,26 și 13,35 în condiții de climatizare standard.

Cuvinte-cheie: constante dimensionale, factor de etanșeitate, metoda FAST 4, lungimea firului

The analysis of dimensional stability of 1x1 RIB CO and CO/LY knitwear

This paper analyzes the impact of knitwear's fiber composition, linear density and finishing of yarn used in the dimensional stability of the 1x1 RIB knitwear made on the same circular knitting machine. Dimensional stability of these samples was analysed by FAST 4 method. Different samples were compared across multiple indicators. The results show that the most stable dyed knitted fabric are made of cotton 96% and 4% of Lycra and of yarn with linear density 19.14 tex. Tightness factor's values in the dry relaxation stood at 17.90, in the wet 18.45, in total 18.73 and 18.59 in air conditioned terms. Knitwear with the highest values of dimensional instability are raw knitted fabric made of 100% CO, and yarn with linear density of 13.39 tex. Tightness factor's values in the dry relaxation stood at 12.16, in the wet 12.36, in total 13.26 and 13.35 in air conditioned terms.

Keywords: dimensional constants, the tightness factor, FAST 4 method, yarn length

INTRODUCTION

Knitted products are clasified as unstable products in dimensional stability point of view. This is due to the fact that, a variety of different loads affect knitwear's production process and also nature of knitwear structure itself. Therefore in the yarn, which has formed a loop, a certain amount of potential energy is accumulated and causes a certain pressure yarn against yarn in places where these yarns intersect in knitwear. On these places, between the yarns frictional forces appear which prevent their displacement. Yarn tends to free of deformations that have occurred in the shaping of the loop which causes a shrinkage. Knitwear's shrinkage stops when these deformation and friction forces are in balance [1].

Due the fact that several external factors simultaneously influence on the shrinking of knitwear, their individual impact is difficult to measure. Therefore, analisys conducts impact of raw materials selection, knitting machine, knitting conditions and the impact of knitwear's finishing [2].

Characteristics of fiber significantly affect knitwear's shrinkage. For example, natural cellulose fibers have a small area of elastic deformation while synthetic fibers are more elastic and much faster occupy steady state [2].

The impact of treatment is also significant. Wet finishing method leads to the relaxation of knitwear. The water molecules during penetration into intermicellar spaces cellulose fibers, lead to swelling of fibers and as result yarn's diameter in the loop increases by 20 to 30 % [3]. Wet processing usually is accompanied by increasing temperature of processing agents [4]. All this leads to shrinkage knitwear.

When designing clothing products nig issue is the prediction of dimensional stability of knitwear. This problem is expressed during the exploitation of knitted products as well as during their washing, because very often there are significant dimensional changes in clothing products that reduce their quality.

MATERIAL AND METHODS

Experimental part of this paper analyses the dimensional stability of the 1x1 RIB knitted fabric made of 100% CO yarns and CO yarns in combination with LY (96% CO/4 % LY). Linear density of LY which was used is 44 dtex. CO yarn was used in two linear densities: 19.14 tex and 13.39 tex. Samples in the raw state and stained samples were examined (table 1).

Knitwear are made on a circular knitting machine type Fv 2.0 of company Mayer & Cie. Characteristics of the machine are as follows: cylinder diameter 19" (inch), the gauge is E18 and with 40 feeders, the

Table 1

Samples	A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4
Structure	1x1 RIB	1x1 RIB	1x1 RIB	1x1 RIB	1x1 RIB	1x1 RIB	1x1 RIB	1x1 RIB
Fiber composition	100% CO	100% CO	96% CO / 4% LY	96% CO / 4% LY	100% CO	100% CO	96% CO / 4% LY	96% CO / 4% LY
Linear density (tex/dtex)	19,14	13,39	19,14/4,4	13,39/4,4	19,14	13,39	19,14/4,4	13,39/4,4
Twists (m–1)	565	693	565 / -	693 / -	565	693	565 / -	693 / -
Finishing	raw	raw	raw	raw	dyed	dyed	dyed	dyed

knitting speed is 1.7 m/s. All of the samples are knitted under the same conditions and same machine.
Dimensional stability of samples was analysed by FAST 4 method. Measurment was performed on 20 samples of the same type and in measurment result in the following, the arithmetic mean values of these 20 samples is represented.

Determination of the dimensional stability by the FAST 4 method

Sample's dimensions were 300 x 300 mm and they were taken with 5 cm minimum distance from the edges of a knitted fabric.
FAST 4 method consists of several stages [5]. First, the conditioned samples of knitted fabric has to be exposed to heat at a temperature of 105 °C in a dryer for 60 min period, after which dimension of samples have to be taken in the longitudinal and transverse direction for a period of 30 seconds (length L1). That is followed by immersion of a dry sample for 30 minutes in water at a temperature of 25 °C to 30 °C with the addition of 0.1% detergent. After that, sample has to be placed on smooth surface with gentle pressing in order to remove excess water, after which the sample should be measured again (length L2). The sample is then returned to the dryer to be exposed to heat at a temperature of 105 °C for 60 min. The dried sample is measured over a period of 30 seconds to obtain the length L3. At the end the sample is left for relaxation, and after conditioning in a room with standard atmospheric conditions according to ISO 139 the sample is measured (length L4).

According to the method FAST 4, relaxing shrinkage is defined as percentage change of knitwear sample's dimension after the heat and wet processing. It can be described as the ratio of the difference between the dry sample length after heat treatment (length L1) and the dimension of the dried sample after relaxation at a wet state (length L3) and dimension of dry sample after the heat treatment (length L1). Relaxational shrinkage of knitwear's sample can be represented by following expression 1 [5]:

$$RS = \frac{L_1 - L_3}{L_1} \cdot 100\ [\%] \qquad (1)$$

FAST 4 method defines relaxing stretching in a wet condition as the percentage change of dimension of the knitwear's sample upon wet treatment and is calculated according to following expression 2 [5]:

$$HE = \frac{L_2 - L_3}{L_2} \cdot 100\ [\%] \qquad (2)$$

RESULTS AND DISCUSSION

Figure 1 shows the values of shrinkage/stretch on horisontal axis for all samples shown in table 1, i.e. for all raw samples: A1, A2, A3 and A4 and stained samples B1, B2, B3 and B4. Figure 2 shows the same values but measured on vertical axis of knitted samples.
In figure 1 and 2, we can see that the raw samples of knitwear made from finer yarns have less shrinkage of the knitted fabric which are made of coarser and stronger yarn. Samples with Lycra show that Lycra contributes to greater stabilization of knitwear. Also it

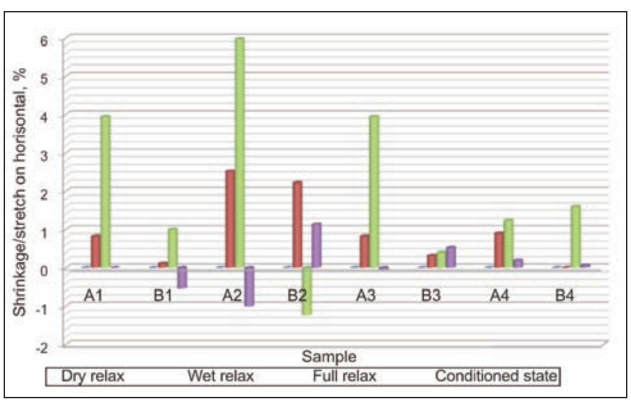

Fig. 1. Results of shrinkage/stretch of knittung material on horisontal

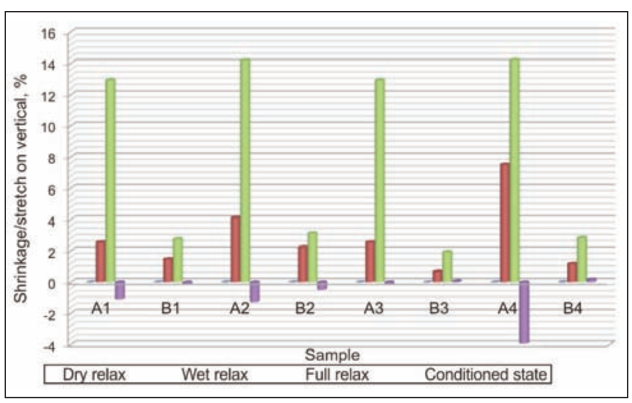

Fig. 2. Results of shrinkage/stretch of knittung material on vertical

can be seen that samples of colored knitwear have a significantly greater dimensional stability than the samples of raw knitwear. This is due to stabilization of knitwear in the technological stage of coloring. This stabilization is further increased when 4% Lycra is added into cotton knitwear. Figures also show that samples of the raw knitted fabric is woven from finer yarns have less vertical and horizontal shrinkage comparing with knitwear made from the coarser and stronger yarn.

Dimensional constants K-values

In order to monitor the stability of the knitted structure through different state of relaxation, dimensional constants can be used. Usually, following Munden's geometrical correlation are used [1] for calculating the dimensional constants of knitwear 4 relaxation conditions:

$$K_c = \frac{D_h}{l}; \quad K_w = \frac{D_v}{l}; \quad K_r = \frac{K_c}{K_w}; \quad K_s = S \cdot l^2 \quad (3)$$

l is the mean value of the yarn's length in a loop, K_c, K_w, K_r and K_s – dimensional constants.

K values are important for prediction of the structural behavior, to create a material with better stability, for determining the minimum/lower energy level of loops after treatment. *K* constants can interconnect values D_h, D_v and yarn's length in a loop. K_w and K_c are constants of D_v and D_h. K_r constant represents the ratio of the constants K_c/K_w. This is a direct measure of a loop's shape and it is called the shape factor of the loop. K_s is a constant overall density of loops. It is the product constants K_c and K_w [1]. Table 2 shows the value of dimensional constants for the test samples.

The results shown in table 2, indicate that the values of the dimensional constants increase with increasing relaxation, except for the conditioned samples where the values decrease. Knitwear made of 96% CO and 4% LY give different values of knitwear made of 100% CO, because they have a greater angle of recovery and this is due to their more elastic properties.

The difference can be seen between raw and dyed knitwear. Constants K_w, K_c and K_s are significantly lower with raw knitwear. Values of the constants rise with the knitted fabric which is made of thicker cotton yarns, comparing with ones made by thinner cotton yarn. Also with the change of the relaxation condition, it can be seen that K_r constant or a loop's shape factor is significantly reduced as a result of achieving a stable condition.

According to the results shown in table 2, knitted fabrics which are made of a mixture of 100% CO and 4% LY faster reach stable condition. It can also be noted that colored knitwear attain stable condition quicker than raw samples.

Tightness factor variations

Tightness factor represents a measure of fabric density and it can be calculated by the following equation 4 [1]:

$$\textit{tightness factor}\ (\mathrm{TF}) = \frac{\sqrt{Tt}}{l} \quad [\mathrm{tex}^{1/2}\mathrm{cm}^{-1}] \quad (4)$$

Or, it can be represented as structural tightness factor [1]:

$$(\mathrm{STF}) = TF \cdot K_s \quad [\mathrm{tex}^{1/2}\mathrm{cm}^{-1}] \qquad (5)$$

where: *TF* is tightness factor, $\mathrm{tex}^{1/2}\mathrm{cm}^{-1}$; *Tt* – linear density, tex; *l* – yarn's length in a loop, cm.

Table 2

		A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4
l	cm	0.280±0.0111	0.289±0.0121	0.0272±0.0122	0.269±0.0079	0.270±0.0048	0.274±0.0063	0.264±0.0046	0.0262±0.0038
Kw	D	3.09±0.0344	3.61±0.0437	4.72±0.0572	4.84±0.0384	3.28±0.0156	3.68±0.0233	5.07±0.0231	5.49±0.0209
	W	3.22±0.0357	3.67±0.0444	4.84±0.0585	5.07±0.0403	3.39±0.0162	3.87±0.0245	5.19±0.0237	5.54±0.0211
	F	3.30±0.0367	4.11±0.0497	5.15±0.0623	5.37±0.0427	3.43±0.0164	4.05±0.0257	5.49±0.0250	5.67±0.0216
	C	3.22±0.0358	4.08±0.0495	5.03±0.0609	5.30±0.0422	3.40±0.0162	4.01±0.0245	5.46±0.0249	5.68±0.0216
Kc	D	6.10±0.0678	6.7±0.0812	6.48±0.0785	6.86±0.0546	6.55±0.0312	7.42±0.0471	7.07±0.0322	7.87±0.0300
	W	6.14±0.0682	6.9±0.0835	6.54±0.0791	6.95±0.0552	6.58±0.0314	7.56±0.0479	7.12±0.0325	7.89±0.0301
	F	6.34±0.0705	7.12±0.0863	7.03±0.0850	6.98±0.0555	6.69±0.0319	7.35±0.0466	7.20±0.0328	8.02±0.0306
	C	6.31±0.0701	7.01±0.0849	7.01±0.0846	6.96±0.0554	6.66±0.0318	7.32±0.0464	7.13±0.0325	8.01±0.0305
Kr	D	1.97±0.0219	1.86±0.0225	1.37±0.0166	1.42±0.0113	2.00±0.0095	2.02±0.0128	1.39±0.0064	1.43±0.0055
	W	1.91±0.0212	1.88±0.0228	1.35±0.0164	1.37±0.0109	1.94±0.0093	1.95±0.0124	1.37±0.0063	1.43±0.0054
	F	1.92±0.0213	1.73±0.0210	1.36±0.0165	1.30±0.0103	1.95±0.0093	1.80±0.0115	1.31±0.0060	1.42±0.0054
	C	1.96±0.0218	1.72±0.0208	1.39±0.0168	1.31±0.0104	1.96±0.0093	1.82±0.0116	1.31±0.060	1.41±0.0054
Ks	D	18.89±0.2099	24.18±0.2929	30.62±0.3706	33.2±0.2639	21.47±0.1024	27.28±0.1731	35.84±0.1632	43.24±0.1647
	W	19.75±0.2195	25.3±0.3064	31.62±0.3826	35.2±0.2798	22.32±0.1065	29.25±0.1854	36.92±0.1684	43.69±0.1665
	F	20.94±0.2326	29.26±0.3543	36.18±0.4377	37.47±0.2979	22.97±0.1096	29.78±0.1888	39.49±0.1801	45.48±0.1733
	C	20.35±0.2261	28.62±0.3466	35.20±0.4260	36.94±0.2937	22.64±0.1080	29.39±0.1863	38.93±0.1775	45.49±0.1733

Legend: D – dry relaxation, W – wet relaxation, F – full relaxation, C – conditioned sample, *l* – the mean value of the yarn's length in a loop (cm).

Table 3

	TF				STF			
	D	W	F	C	D	W	F	C
A_1	14.93	15.14	16.32	16.20	281.99	299.05	341.77	329.72
A_2	12.16	12.36	13.26	13.35	293.98	312.76	387.87	382.20
A_3	16.96	17.20	18.73	18.59	519.43	544.07	677.67	654.40
A_4	15.01	15.51	16.04	16.16	498.38	545.83	600.85	597.02
B_1	15.79	16.14	16.51	16.45	339.10	360.37	379.21	372.40
B_2	12.88	13.21	13.65	13.55	351.54	386.37	406.64	398.29
B_3	17.90	18.45	18.73	18.59	641.58	681.14	739.85	723.68
B_4	15.80	15.98	16.41	16.22	683.08	698.09	746.37	738.02

Legend: D – dry relaxation, W – wet relaxation, F – full relaxation, C – conditioned sample.

Table 4

Sample		A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4
Coefficients TF	a_0	78.0925	62.9388	89.2732	78.4514	80.9362	66.7810	91.6991	80.5603
	a_1	–557.9346	–435.0830	–655.7698	–582.9026	–600.1090	–487.4101	–696.0883	–614.4097
	a_2	1992.9112	1500.3595	2410.9583	2166.8203	2222.6825	1778.8273	2637.8772	2345.1497
	a_3	–3558.7856	–2586.8595	–4431.9287	–4027.6379	–4116.1078	–3246.0707	–4994.1072	–4475.1907
	a_4	2542.0085	1784.0234	3258.8111	2994.5252	3048.9752	2369.3912	3783.3881	3416.4758

Table 3 shows that the value of the *TF* decreases from full, through a wet to dry relaxation. Knitwear made of 96% CO and 4% LY mixture faster returns to its original state due to Lycra effect compared to knitwear made from 100% cotton. This contributes to the rapid establishment of a stable condition in these knitwear. It is also reducing the length of the yarn loops is more evident in knitted fabric containing Lycra which gives a higher values of *TF*. Table 4 also shows that thicker knitwear provides greater value of *TF* comparing with knitwear made of thinner yarn. Also, colored knitwear have higher *TF*, because during coloring process kneatwear was exposed to temperature tratment and wet processing.

Mathematical model for describing relation between TF and value of the yarn's length (l_0) in knitwear's loop

To determine TF dependencies from yarn's length in the knitwear's loop, specific mathetmatical model is introduced. In order to represent method of nonlinear regression, polynomial model is used. For a given set of data pairs (x_1,y_1), (x_2,y_2), K, (x_n,y_n), the following relation should be found, $y = a_0 + a_1x + K + a_mx^m$, whereby $m \leq n - 2$, so experimental data can be the best represented.

The results of experimental research have been approximated by a non-linear model fitting data which has a form of polynomial of degree 4:

$$TF = a_0 + a_1 l + a_2 l^2 + a_3 l^3 + a_4 l^4 \qquad (6)$$

wherein a_0, a_1, a_2, a_3, a_4 are constants, l_0 independant variable i.e. length of yarn in the loop twists. As l_0 changes in knitwear depending on relaxation, that's *TF* value changes according to the previous formula. Table 4 gives an overview of the calculated coefficients of the empirical formula for the *TF* value changes depending on the length of yarn in the loop.

CONCLUSIONS

This paper analyzes the impact of raw material composition of knitwear, finishing method and fineness of used yarn on dimensional stability of the 1x1 ribbed knitwear made on the same circular knitting machines. The results obtained show that the most stable are dyed knitwear made of CO 96% and 4% of LY and yarn fineness 19.14 tex. According to the results, the knitted fabric with the highest degree of dimensional instability are raw knitted fabric of 100% CO, yarn made of fineness 13.39 tex.

It can be concluded that values *Kc* and *Kw* increase at knitwear which have LY in their structure, as well as at those which are dyed and those which are made of thinner yarn. *Kr* decreases with an increase of relaxation which means that the loop reaches its stable state and it has minimal ability to change shape. *Ks* factor raises significantly with the increase of relaxation and with increase of the *TF*.

It can be concluded that knitwears which show the most stable condition are dyed knitwears made of CO and LY and of thicker yarns. Knitwears with the highest degree of dimensional instability are made of raw knitted fabric of 100% CO, and of thinner yarn. In complete relaxation, all samples have recorded the largest dimensional change.

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