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Study of Changes in Tensile Cyclic Characteristics of Cotton /Acrylic Blended Yarn after Knitting Process

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Influence of the knitting process and density on the tensile characteristics of cotton/ acrylic blended yarns were studied. In the paper 1st cycle tensile characteristics of initial blended yarns and yarns obtained after deknitting knitted fabrics were compared. It was stated that after knitting all 1st cycle tensile characteristics as specific stress, plastic strain, degree of elasticity and hysteresis, have changed. After knitting process all examined yarns had lost their elasticity and the values of their plastic strain increased. After knitting the values of hysteresis of tested cotton/acrylic blended yarns sufficiently increase too. All tested indices of the yarns depend on the value of total strain. Knitting density especially influences upon the 1st cycle tensile characteristic, as specific stress, but don't influence upon the plastic strain, elasticity and hysteresis of tested blended yarns.

Keywords: cotton/acrylic blended yarns, density of knits, cyclic tensile characteristics, initial and deknitted yarns.

INTRODUCTION

Nowadays, fabrics knitted from cotton/acrylic blended yarns are very popular. In comparison with classic cotton outwear knits manufactured from blended yarns have better quality characteristics, such as strength, elongation at break, elasticity, flexibility, shrinkage, handle and others [1]. For the high-efficiency knitting machines currently used yarn of better quality is required [2]. Among tensile parameters of the yarn, its elasticity is of special importance. Elasticity is the feature of the material, which characterizes its ability to reproduce the initial shape and size after external loads are removed [3]. Yarn elasticity is usually characterized by the degree of elasticity [4, 5].

The goal of achieving structural stability against unrecoverable extension, resistance against wear and some other properties of knits, qualifies a high percentage of blended yarns for use in the production of high quality. Despite the effect of such synthetic fibres as polyamide and especially polyester in blend composition is well known, the knittability and wearing properties of cotton/PAN blends is not sufficiently investigated.

The mechanical properties of weft knitted fabrics are strongly related to fabric structure and yarn properties.

It is known that the knitting density is one of the parameters having the greatest influence on some characteristics of knitted fabrics as handle, comfort, weight and most importantly, fabric dimensional stability [6 – 8]. However, the tensile behavior of yarns after knitting process has not received much attention so far [9, 10]. The importance of such experiments for the knitters would be an approach for the comparison of yarn behavior during knitting without long-lasting experiments on different machines.

The aim of this paper is to define the effect of knitting process and density of knitwear on the change in tensile cyclic characteristics of 50 % cotton / 50 % acrylic blended yarns.

MATERIALS

The experiments were carried out with the 30.7 tex × 2 50 % cotton / 50 % PAN ring spun blended yarns. From those yarns 3 samples knitted in real different course density (from 8 cm^{-1} till 10 cm^{-1}) were prepared (Table 1). The samples were knitted in the most popular structure for outwear knits a rib 1×1 pattern on a flat V-bed knitting machine at the same cam setting in a gauge of 10 E. The main principle used in these experiments was the comparison of the set of properties of initial (*IY*) and knitted yarns, i.e. the yarns (*DY*) obtained after deknitting fabrics.

Scheme of the experimental material is presented in Figure 1. The knitted fabrics differed only in their stitch density, being defined as minimum I (8), medium II (9) and maximum III (10). In practice it is dominated as loose, medium and tight densities. As it was discussed above, stitch density of knitted fabrics is one of the parameters having the greatest influence on some characteristics of knits.

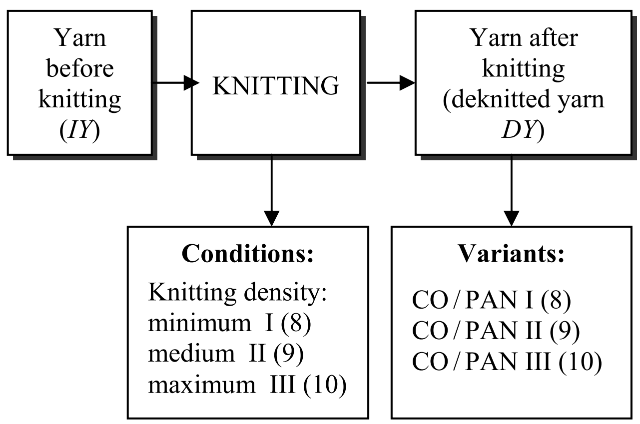

Fig. 1. Scheme of the experimental material

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Table 1. Knitted samples

Samples code	Courses per cm	Wales per cm	Fabric density, cm^{-2}	Area density, g/m^2	Stitch length, cm	Tightness factor
I (8)	8.0	5.0	40.0	275.0	0.56	14.0
II (9)	9.0	5.0	45.0	287.4	0.53	15.0
III (10)	10.0	5.0	50.0	300.8	0.49	16.0

EXPERIMENTAL METHODS

All experiments were carried out in standard atmosphere for testing according to the standard ISO 139.

The tightness of knitted samples was characterized by the tightness factor (*TF* or *K*). When compared structures of the same type the formula [2] is used:

$$TF = \frac{\sqrt{T}}{l}, \qquad (1)$$

where T is the yarn linear density in tex, l is the stitch length in cm.

The determination of linear density of deknitted yarns was carried out by inserting the specimen in the clamps of tensile tester with a pretension 0.15 cN/tex [11]. Then the specimen was cut and weighed.

The tensile properties of initial yarns and yarns obtained after deknitting knitted fabrics were studied. The tensile characteristics of cotton/acrylic blended yarns were determined using universal testing machine ZWICK/Z 005. The determination of breaking force and elongation at break of analyzed yarns was obtained following the standard ISO 2062.

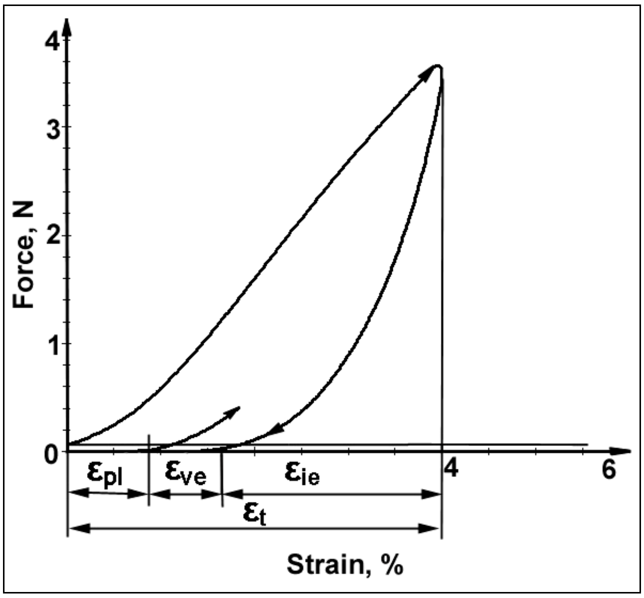


Fig. 2. Computer print-out of the yarn's 1st cycle test diagram: F – stress, N; ε_t – total strain, %; ε_{pl} – plastic strain, %; ε_{ve} – viscoelastic strain, %; ε_{ie} – immediate elastic strain, %

Viscoelastic behavior of the analyzed yarns was revealed by means of hysteresis curve (Fig. 2). The gauge length in the tests was 500 mm. The yarns after pretension of 0.1 cN/tex were subjected to constant rate extension of 50 mm/min. The level of total strain was 2, 4, 6 and 8 %. The values of yarn's 1st cycle tensile indices were determined from the hysteresis curve (Fig. 2).

Hysteresis *HY* (%) of the yarn was calculated according to the formula:

$$HY = \frac{WF_l - WF_{un}}{WF_l} \cdot 100\ \%, \qquad (2)$$

where WF_l is the loading work in N·mm; WF_{un} is the unloading work in N·mm.

The ratio of the elastic strain to the total strain may be used as a criterion of elasticity. The degree of elasticity *DE* of the yarn is expressed as a ratio of elastic strain $\varepsilon_{el} = \varepsilon_{ie} + \varepsilon_{ve}$ (ε_{ie} – immediate elastic strain, ε_{ve} – viscoelastic strain) to the total strain ε_t.

$$DE = \frac{\varepsilon_{el}}{\varepsilon_t} \cdot 100\ \%. \qquad (3)$$

Plastic strain ε_{pl} occurs after the tensile forces exceed the limit value of the so-called flow of yarn. Furthermore specific stress f and hysteresis *HY* were determined at different deformation of the tested yarns.

RESULTS AND DISCUSSION

Taking into account the fact that the stress the yarns during knitting causes some mechanical deterioration of yarn, changes in their tensile characteristics usually is studied [7]. The data from the Table 2 indicate the insignificant loss of breaking strength after knitting for cotton/acrylic blended yarns. The loss of yarn strength insignificantly increases with intensification of the knitting density. Contrary to the breaking strength deknitted yarns samples showed an insignificant higher value of elongation at break. The influence of knitting density on the yarn's elongation at break is not visible. After knitting the tested yarns were stretched and lost their rigidity. So, the values of their initial modulus decrease. Analogous test results were obtained by T. Tadic et al. [8]. They investigated the influence of knitting conditions on the change in cotton yarn tensile properties.

Our investigations of viscoelastic behavior of initial and deknitted cotton/acrylic yarns are presented in the Fig. 3 – 7. According to the results obtained in these studies the knitting process affects the 1st cycle tensile characteristics of examined blended yarns. It is evident that the values of elastic and plastic strain depend on the value of the load or the total strain of the material. Any increase in the load or strain results in decreasing the elastic components and increasing the plastic strains.

The data in Fig. 3 show that after knitting at all values of total examined strain the values of specific stress f of

Table 2. Tensile characteristics of cotton / acrylic yarns before and after knitting

Characteristics	Initial yarn	Deknitted yarn code		
		I (8)	II (9)	III (10)
Linear density, tex	61.4	61.8	62.4	61.4
Breaking tenacity, cN/tex	12.9	12.4	12.4	12.2
Elongation at break, %	11.0	12.5	12.6	11.2
Initial modulus, cN/tex	193.0	170.0	178.0	178.0
Work at maximum force, N·mm	294.0	323.0	336.0	236.0
Coefficients of variation, %				
for linear density	1.4	1.0	1.7	1.4
for breaking force	2.4	4.0	4.1	2.7
for elongation at break	9.6	10.9	14.2	8.6
for initial modulus	5.5	8.8	12.0	9.6

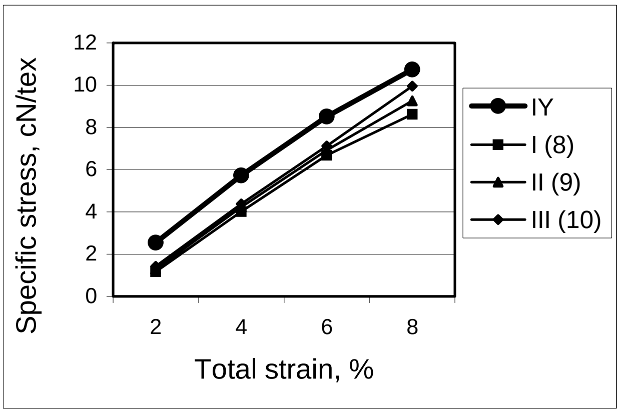


Fig. 3. Dependence of specific stress f of the cotton / acrylic blended yarns upon the total strain ε_t: *IY* – initial yarn; I (8), II (9), III (10) – deknitted yarns

deknitted yarns considerably decrease. After being strained 2 %, the values of specific stress of deknitted yarns decrease from 54 % to 44 % (in regard to the value f of initial yarn) subject to yarn's course density. As total strain $\varepsilon_t = 8$ %, the values of parameter f decreases from 20 % to 7 %. The specific stress of examined yarns depends upon the knitting density. As knitting density increases the values of specific stress grow too (from 7 % to 22 %) at all total deformations of tested yarns. Student's test for yarns II (9): $t_{f2\%} = 22.5$; $t_{f4\%} = 17.8$; $t_{f6\%} = 23.9$; $t_{f8\%} = 9.6$; $t_{99} = 3.25$; $t_{95} = 2.26$, i.e. $t_f > t_{99}$.

The dependence of the plastic strain ε_{pl} of tested yarns upon the total strain ε_t and knitting density is evident from the data presented in Fig. 4. After knitting the values of plastic strain ε_{pl} of deknitted yarns significantly increase. As total strain $\varepsilon_t = 2$ %, the value of plastic strain of deknitted yarns increases from 59 % to 53 %; as $\varepsilon_t = 8$ %, the value ε_{pl} increases only from 8 % to 11 %, thus creep causes additional elongation. The influence of knitting process is less evident at the higher values of total strain. Also we may see that the values of plastic strain of tested blended yarns don't depend upon the real changes of course density for all examined values of total strain.

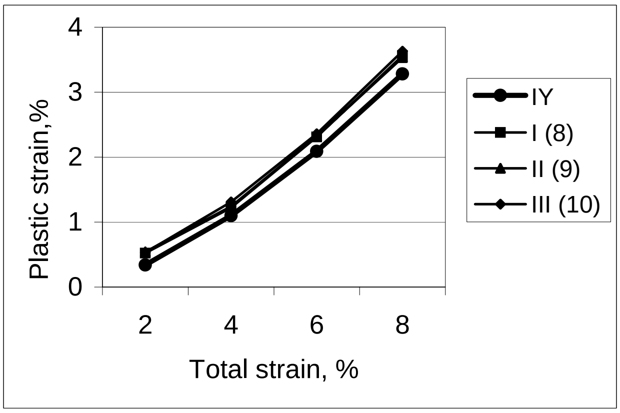


Fig. 4. Dependence of the plastic strain ε_{pl} of cotton / acrylic blended yarns upon the total strain ε_t: *IY* – initial yarn; I (8), II (9), III (10) – deknitted yarns

The dependence of the degree of elasticity *DE* of tested yarns upon the total strain and knitting density is presented in Fig. 5. Analyzing the results of the yarn elasticity, we can see that after knitting blended yarns lost their elasticity. After being strained 2 %, the values of *DE* are lower about 12 %. As $\varepsilon_t = 8$ %, the elasticity of deknitted yarns is only from 5 % to 8 % lower then initial yarns. It is evident that the elasticity of tested yarns depends on total strain of specimens. As in the case of plastic strain, the influence of knitting process on yarn's elasticity is less evident at higher values of total strain. The tested yarns elasticity doesn't depend upon the knitting density.

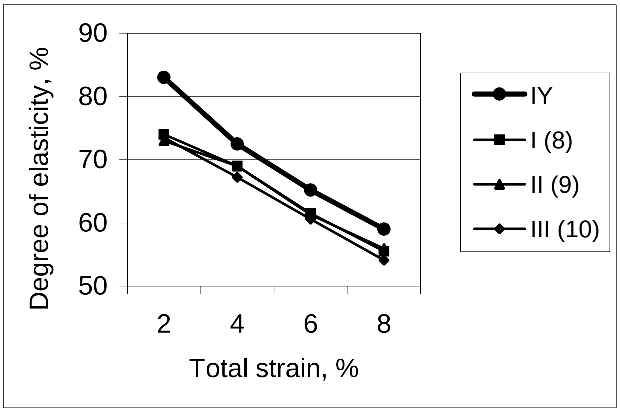
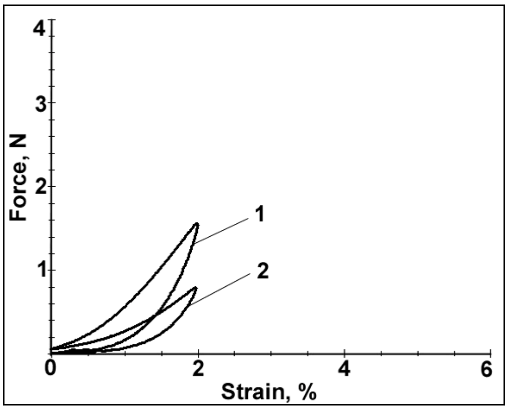


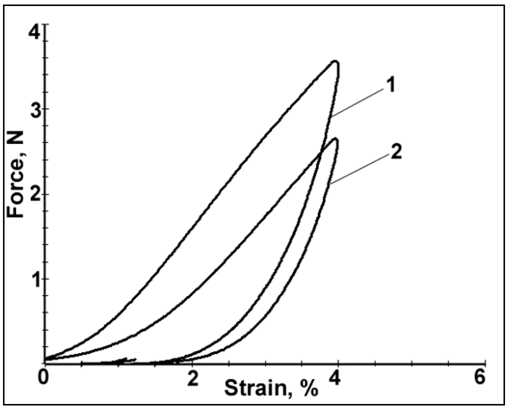
Fig. 5. Dependence of the degree of elasticity *DE* of cotton / acrylic blended yarns upon the total strain ε_t: *IY* – initial yarn; I (8), II (9), III (10) – deknitted yarns

Higher deformation degree means more significant structural changes and leads to higher hysteresis. The data on 1st tensile cycle hysteresis *HY* (%) of cotton/acrylic blended yarns before and after knitting are presented in Fig. 6 and 7. It can by noticed that hysteresis of tested yarns significantly depends upon the knitting process. After knitting the values of yarns hysteresis decrease from 49 % to 62 % in regard to the value *HY* of initial yarns (~56 %, as $\varepsilon_t = 2$ %; ~62 %, as $\varepsilon_t = 4$ %; ~56 %, as $\varepsilon_t = 6$ % and from 49 % till 54 %, as $\varepsilon_t = 8$ %).

The dependence of deknitted yarns hysteresis upon the knitting density is negligible.



a



b

Fig. 6. Influence of knitting process on the 1st cycle hysteresis of blended yarns: 1 – initial yarn; 2 – deknitted yarn II (9): a – total strain ε_t = 2 %; b – total strain ε_t = 4 %

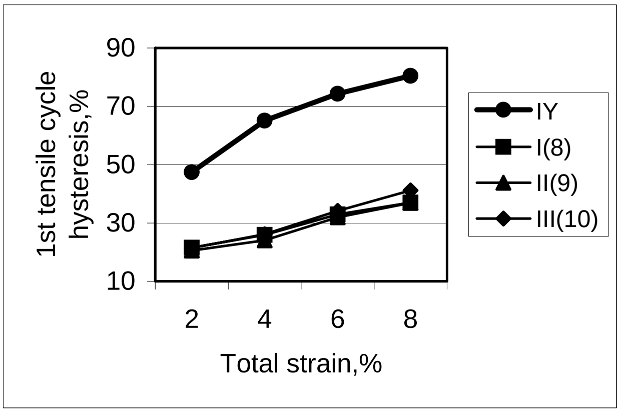


Fig. 7. 1st tensile cycle hysteresis *HY* (%) of cotton / acrylic blended yarns before and after knitting

CONCLUSIONS

Influence of the knitting process and density of knits on the tensile cyclic characteristics of 50 % cotton / 50 % PAN blended yarns were studied.

It has been determined that viscoelastic behavior of all investigated yarns after knitting has changed. At all examined values of total strain 1st cycle specific stress of tested yarns considerably diminished. It was estimated that after knitting blended yarns had lost the elasticity, and their plastic strain increased. Degree of elasticity of deknitted yarns became from 12 % to 5 % lower than yarns before knitting. The values of tested yarns 1st cycle hysteresis considerably decreased too.

The real changes ($8 - 10\ cm^{-1}$) of course density during knitting don't influence upon the 1st cycle tensile characteristics as plastic strain, elasticity and hysteresis of cotton/acrylic yarns. However, it was stated that as knitting density increases the values of specific stress of blended yarns substantially increases too from 7 % to 22 % in regard to the value of initial yarn.

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