ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 10, No. 1. 2004

The Effect of Knitting and Wearing Conditions on the Tensile Characteristics of Blended Yarns

B. Tvarijonavičienė*, I. Šaulytė, G. Laureckienė

Department of Textile Technology, Kaunas University of Technology, Studentų 56, LT-3031 Kaunas, Lithuania

Received 29 September 2003; accepted 21 October 2003

In this paper, the effect of knitting, washing procedures and tumbling in Pilling box tester on the changes in tensile characteristics of blended yarns is analyzed and discussed. The tested yarns obtained after deknitting fabrics differed in their compactness. The rib knitted samples were produced on a flat V-bed knitting machine in a gauge of 10E from two yarn compositions, i.e. 50 % merino wool / 50 % acrylic and 50 % cotton / 50 % acrylic. After knitting the samples were domestic washed and dried. Then they were tumbled in Pilling box tester. A study of the tensile characteristics (breaking force, elongation of break, work at maximum force at break, initial elasticity modulus) of initial and deknitted yarns is presented. The stress-strain curves of initial and deknitted yarns from fabrics of various densities are discussed. The changes in tensile indices of yarns deknitted from unwashed, washed (1, 3 and 5 cycles) and tumbled samples are compared.

Keywords: blended yarns, tensile characteristics, density of knits, washing procedure, tumbling in Pilling box tester.

INTRODUCTION

The mechanical properties of weft knitted fabrics are strongly related to fabric structure and tensile properties of yarns from which they are manufactured.

The goal of achieving structural stability against unrecoverable extension, resistance against wear, fabric cover and some other properties of knits, qualifies a high percentage of plied blended yarns for use in the production of high quality. The main purpose of this study was to estimate the importance of mechanical deterioration of the yarn during knitting under very restricted variation of the knitting parameters, i.e. taking into consideration only some influence of the density of knits, as one of the parameters having the greatest influence on the mechanical and hand properties of knitwear [1, 2].

The importance of such experiments for the knitters would be an approach for the comparison of different yarns behaviour during knitting without long-lasting experiments on different machines.

The aim of this paper is to define the effect of knitting, washing procedure and tumbling in Pilling box tester on the change in tensile characteristics of blended yarns.

EXPERIMENTAL

It is known that after knitting and finishing processes the yarns change their physical-mechanical properties [1 – 3]. We were interested in an effect of knitting and washing processes to the stress-strain behaviour of blended yarns.

Materials. The investigations were carried out with the yarns different in blend composition, i. e. merino wool / / PAN and cotton / PAN. From those two yarns compositions 6 samples of different density of knits were prepared (Table 1). The samples were knitted in a rib pattern on a flat V-bed knitting machine in a gauge of 10E.

After knitting the samples were domestic washed and dried [4, 5]. Then knitted unwashed and washed samples were abraded in Pilling box tester.

The tightness of knits was characterized by the tightness factor (*TF*). When comparing structures of the same type and yarn in a similar states of relaxation, it is used the formula:

$$TF \quad \text{or} \quad K = \sqrt{T}/l\,, \tag{1}$$

where T is the yarn linear density in tex, l is the stitch length in mm [6].

The main principle used in these experiments was the comparison of the set of properties of initial and knitted yarns, i.e. the yarns obtained after deknitting knitted fabrics.

Scheme of the experimental material is presented in Fig. 1. The tested ring spun yarns differed in blend composition and the knitted fabrics differed only in their stitch density, being defined as minimum (I), medium (II) and maximum (III). The stitch density of knits is one of the parameters having the greatest influence on some characteristics of knits.

Methods. In this research we compared the tensile properties of initial yarns and yarns obtained after deknitting knitted, washed and tumbled fabrics. The stress-strain characteristics of blended initial and deknitted yarns were studied. The analysis were carried out according to LST EN ISO 2062, 1995 standard using the ZWICK/Z005 testing equipment [7].

Washing procedure of knits was carried out in an automatic washing machine (1, 3 and 5 cycles) according programme for wool and cotton fabrics [4]. The samples were tumbled in Pilling box tester according to International tester Standard ISO/FDIS 12945-1/2000 [8]. The box was rotated at 60 ±2 revs./min. Tumbling time – 5 hours (18 000 revs.). The samples were used for testing after storage for at least 72 hours in a conditioned laboratory (65 ±2 % RH, 20 ±2 °C).

*Coresponding author. Tel.: + 370-37-353862.; fax: + 370-37-353989.
E-mail address: *beata.tvarijonaviciene@ktu.lt* (B. Tvarijonavičienė)

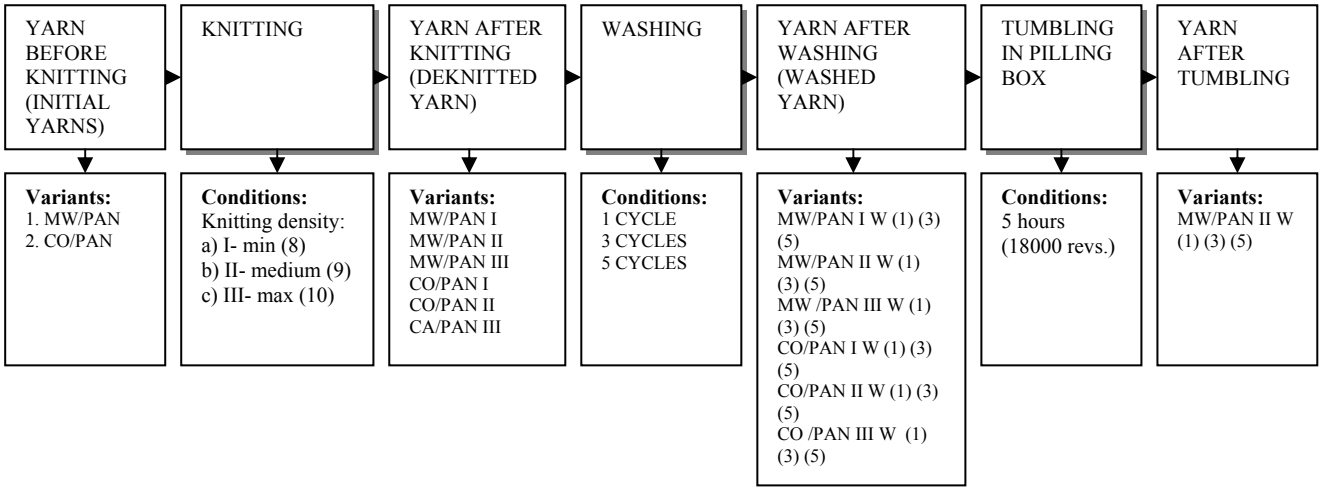

Fig. 1. Scheme of the experimental material

Table 1. Knitted samples

No of sample	Yarn's linear density, tex	Yarn's composition*	Fabric pattern	Courses per cm	Wales per cm	Fabric density, stitches / cm²	Fabric tightness factor *TF*
1	35.7×2	50 MW / 50 PAN	Rib 1×1	8.0	5.5	44.0	1.4
2	35.7×2	50 MW / 50 PAN	Rib 1×1	9.0	6.0	54.0	1.5
3	35.7×2	50 MW / 50 PAN	Rib 1×1	10.0	6.0	60.0	1.8
4	33.3×2	50 CO / 50 PAN	Rib 1×1	8.0	5.0	40.0	1.4
5	33.3×2	50 CO / 50 PAN	Rib 1×1	9.0	5.0	45.0	1.5
6	33.3×2	50 CO / 50 PAN	Rib 1×1	10.0	5.0	55.0	1.6

*MW – merino wool fibre, PAN – acrylic fibre, CO – cotton fibre

RESULTS AND DISCUSSION

Taking into account the fact that the stress the yarns receive during knitting includes some mechanical deterioration of them and that could change their tensile characteristics. The main tensile properties of blended yarns were compared.

The tensile characteristics of initial and deknitted yarns are presented in the Table 2. In the Fig. 2 and 3 we can see the representative stress-strain curves of blended wool / acrylic (Fig. 2) and cotton/acrylic (Fig. 3) yarns. As the results obtained in these studies revealed that the knitting process affects the tensile characteristics of tested blended yarns. The influence of knitting process on the tensile indices of wool / acrylic and cotton / acrylic yarns is not the same.

After knitting the tested wool / acrylic yarns lost their breaking strength (Student's coefficient [9] $t_F = 2.77$, $t_{95} = 2.01$, $t_{99} = 2.68$, i.e. $t_F > t_{99}$), while the change of its elongation at break is significantly small ($t_{\varepsilon H} = 2.53$, i.e. $t_{95} < t_{\varepsilon H} < t_{99}$). The breaking tenacity of the tested yarns after knitting does not change. The values of initial elasticity modulus of wool / acrylic yarns after knitting considerably decrease ($t_E = 5.70$, $t_{95} = 2.02$, $t_{99} = 2.7$, i.e. $t_E > t_{99}$). We can say that after knitting the wool / acrylic yarns lost their rigidity. The changes of course density (in real conditions) of knits don't effect the breaking strength and elongation at break of tested wool / acrylic yarns. The data from Fig. 2 enable an insight into the differences of the stress-strain curves of initial *(S)* wool / acrylic yarns and deknitted from samples with different course density (I(8), II(9), III(10)).

The data from the Table 2 indicate the significantly loss of breaking strength after knitting for cotton / acrylic yarns ($t_F = 2.47$, $t_{95} = 2.02$, $t_{99} = 2.70$, i.c. $t_{95} < t_F < t_{99}$). The loss of yarn strength increases with intensification of the knitting density. Contrary to the breaking strength the deknitted cotton / acrylic yarns samples showed a greater elongation at break (Fig. 3). The influence of the real knitting conditions on the character of the changes in the yarn elongation at break is not visible. The cotton / acrylic yarns showed the least important change of elongation at break only under the conditions of minimum density. The results from the Table 2 and Fig. 3 confirm the influence of knitting process to the change on the values of initial elasticity modulus of cotton / acrylic yarns. After knitting process the values of initial elasticity modulus of cotton / / acrylic yarns considerably decrease ($t_E = 6.20$, $t_{95} = 2.02$, $t_{99} = 2.7$, i.e. $t_E > t_{99}$). As in the case of wool / acrylic yarns after knitting cotton / acrylic yarns lost their rigidity.

The influence of the washing conditions on the tensile characteristics of blended wool / acrylic yarns is evident from the data presented in the Table 3. The data show the washing process of knitted samples causes some changes in the tensile characteristics of tested yarns. After 1st washing cycle in all knitted conditions wool / acrylic yarns lost their breaking strength significantly (from 1.6 till 2.9 %). There are no changes in yarns elongation at break. After washing process tested wool / acrylic yarns became less rigid (from 0.5 till 8.9 %). The influence of the

Table 2. Tensile characteristics of initial and deknitted blended yarns

Yarn type	Nominal course density of knits st./cm	Linear density *T*, tex	Maximum force at break *FH*, N	Breaking tenacity *RH*, cN/tex	Strain at max. force *εH*, %	Work at max. force *WH*, Nmm	Initial elasticity modulus *E* (100%), cN/tex
50 % MW / / 50 % PAN	Initial yarn (IY)	69.4 ±0.6	7.64 ±0.14	11.0 ±0.1	20.9 ±0.6	592 ±24	198 ±4
	I (8)	68.4 ±0.6	7.38 ±0.12	10.8 ±0.1	21.8 ±0.4	578 ±19	180 ±6
	II (9)	69.4 ±0.5	7.56 ±0.13	10.9 ±0.1	21.6 ±0.6	592 ±22	175 ±4
	III (10)	70.3 ±0.6	7.39 ±0.15	10.5 ±0.2	21.2 ±0.6	569 ±24	172 ±7
50 % CO / / 50 % PAN	Initial yarn (IY)	61.4 ±0.4	7.91 ±0.10	12.9 ±0.1	11.0 ±0.6	294 ±21	193 ±5
	I (8)	61.8 ±0.3	7.70 ±0.14	12.4 ±0.1	12.5 ±0.3	323 ±26	170 ±7
	II (9)	62.4 ±0.5	7.71 ±0.15	12.4 ±0.2	12.6 ±0.8	336 ±30	178± 10
	III (10)	61.4 ±0.4	7.49 ±0.11	12.2 ±0.1	11.2 ±0.5	236 ±19	178± 8

Table 3. Tensile characteristics of wool / acrylic yarns before and after washing procedure

Course density	Number of washing cycles	Linear density *T*, tex	Maximum force at break *FH*, N	Breaking tenacity *RH*, cN/tex	Strain at max. force *εH*, %	Work at max. force *WH*, Nmm	Initial elasticity modulus *E* (100%), cN/tex
I (8)	0	68.4	7.38 ±0.12	10.8 ±0.1	21.8 ±0.4	578 ±19	180 ±6
	1	69.5	7.20 ±0.13	10.4 ±0.1	21.6 ±0.5	558 ±19	164 ±5
	3	71.5	7.40 ±0.12	10.4 ±0.1	22.5 ±0.5	591 ±19	158 ±4
	5	71.9	7.31 ±0.07	10.2 ±0.1	22.3 ±0.5	575 ±17	151 ±3
II (9)	0	69.4	7.56 ±0.13	10.9 ±0.1	21.6 ±0.6	592 ±22	175 ±4
	1	72.0	7.34 ±0.12	10.2 ±0.1	22.0 ±0.6	576 ±19	169 ±5
	3	71.0	7.18 ±0.15	10.1 ±0.2	22.0 ±0.8	560 ±26	163 ±4
	5	71.6	7.17 ±0.11	10.0 ±0.1	21.8 ±0.6	553 ±21	158 ±4
III (10)	0	70.3	7.39 ±0.15	10.5 ±0.2	21.2 ±0.6	569 ±25	172 ±7
	1	69.9	7.27 ±0.19	10.4 ±0.2	21.4 ±0.5	559 ±23	171 ±6
	3	69.4	7.52 ±0.13	10.6 ±0.1	22.4 ±0.7	600 ±25	174 ±5
	5	71.4	7.12 ±0.15	10.0 ±0.2	22.3 ±0.6	562 ±23	165 ±4

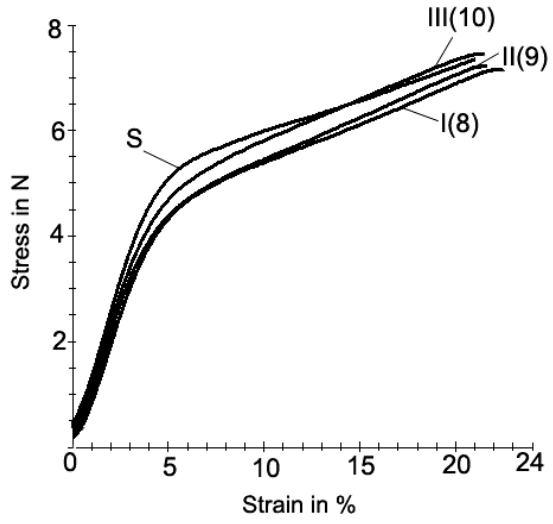

Fig. 2. The representative stress-strain curves of MW / PAN blended yarns: *S* – initial yarns; I ,II, III – deknitted yarns

washing cycles on this yarn property is also visible, showing a rather regular diminution of the yarn rigidity with increasing of washing cycles in comparison with this property of the unwashed samples. Changes in the values of yarns initial modulus more evident in case of the minimum knitting density.

The influence of the washing conditions on the tensile characteristics of blended cotton / acrylic yarns is evident from the data presented in the Table 4. The represented data show the washing operation causes more significantly change in the behaviour of cotton / acrylic yarns in comparison with these properties of wool / acrylic yarns. After 1st washing cycle of samples cotton / acrylic yarns change its tensile properties. Maximum force at break *FH* after 1st and 3rd washing cycles of tested yarns increases. Contrary to the breaking strength the deknitted yarns show a rather regular diminution of elongation at break in all cases of knitting conditions. After 1st washing cycle yarns lost their elongation at break from 8.0 till 15.1 % and after 5th washing cycle the elongation at break of them is from 17.9 till 29.4 % lower in comparison with unwashed samples. The influence of knitting conditions on this yarn indice is no visible. The decrease of elongation at break of cotton / acrylic yarns after washing causes diminution of its work at maximum force too. After washing procedure the tested yarns were relaxed and the initial elasticity modulus of them has the lower values in all cases of knitting conditions. The change of course density of knits has no influence on this tensile indice of tested yarns. After 1st

Table 4. Tensile characteristics of cotton / acrylic yarns before and after washing procedure

Course density	Number of washing cycles	Linear density T, tex	Maximum force at break FH, N	Breaking tenacity RH, cN/tex	Strain at max. force εH, %	Work at max. force WH, Nmm	Initial elasticity modulus E (100 %), cN/tex
I (8)	0	61.8	7.70 ±0.14	12.4 ±0.1	12.5 ±0.3	323 ±26	170 ±7
	1	63.0	7.71 ±0.12	12.2 ±0.1	11.1 ±0.8	270 ±28	161 ±7
	3	63.9	7.72 ±0.11	12.1 ±0.1	10.1 ±0.5	234 ±16	149 ±9
	5	62.0	7.64 ±0.12	12.3 ±0.1	9.0 ±0.4	198 ±11	164 ±3
II (9)	0	62.4	7.71 ±0.15	12.9 ±0.1	12.6 ±0.8	336 ±30	178 ±10
	1	64.5	7.79 ±0.13	12.1 ±0.1	10.7 ±0.6	263 ±20	166 ±16
	3	62.3	8.20 ±0.16	13.2 ±0.2	9.9 ±0.5	237 ±15	163 ±9
	5	62.2	7.92 ±0.08	12.7 ±0.1	8.9 ±0.4	199 ±11	163 ±12
III (10)	0	61.4	7.52 ±0.11	12.2 ±0.1	11.2 ±0.5	279 ±16	178 ±8
	1	62.4	8.13 ±0.09	13.0 ±0.1	10.3 ±0.5	252 ±20	159 ±7
	3	62.2	7.80 ±0.14	12.5 ±0.1	9.5 ±0.5	215 ±16	162 ±10
	5	63.9	7.72 ±0.11	12.1 ±0.1	9.2 ±0.4	205 ±13	163 ±9

Table 5. Tensile characteristics of deknitted wool / acrylic yarns after tumbling in Pilling box and washing procedure

Procedure	Washing cycles	Linear density T, tex	Max. force at break FH, N	Breaking tenacity RH, cN/tex	Strain at max. force εH, %	Work at max. force WH, Nmm	Initial elasticity modulus (100 %) E, cN/tex
Initial	0	69.4	7.56 ±0.13	10.9 ±0.1	21.6 ±0.6	592 ±22	175±4
Tumbled	0	61.5	7.07 ±0.24	11.5 ±0.2	21.4 ±0.8	548 ±34	207±7
Tumbled	1	63.3	6.78 ±0.20	10.2 ±0.2	21.5 ±0.7	517 ±26	190±10
Tumbled	3	63.0	7.07 ±0.18	10.3 ±0.2	21.9 ±1.1	547 ±34	193±10
Tumbled	5	62.8	6.42 ±0.23	10.9 ±0.2	20.6 ±1.0	470 ±37	181±6

washing cycle the initial elasticity modulus of cotton / acrylic yarns decreased from 5.0 till 10.7 %. Further washing cycles don't point up noticeable changes to this indice.

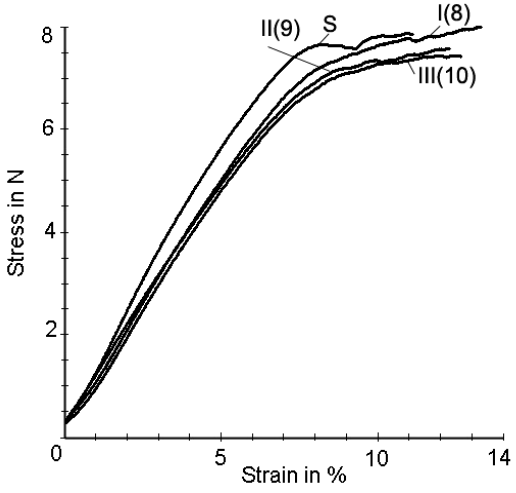

Fig. 3. The representative stress-strain curves of CO / PAN blended yarns: *S* – initial yarns; I ,II, III – deknitted yarns

The deterioration of the yarn after knits tumbling procedure in Pilling box as imitation of wearing conditions may be expressed by relation of analogous tensile indices of the deknitted yarns before and after tumbling. The sence of this relation is the possibility of a simple elvaluation of the change in the yarn quality caused by tumbling process. The value of "1" indicates the absence of any change, and the values smaller or greater than "1" indicates a relative improvement or deterioration of the properties of the yarn.

There was tumbled (18000 revs.) one type of samples (see Fig. 1) from wool / acrylic blended yarns before and after washing. Their tensile characteristics of them are represented in the Table 5.

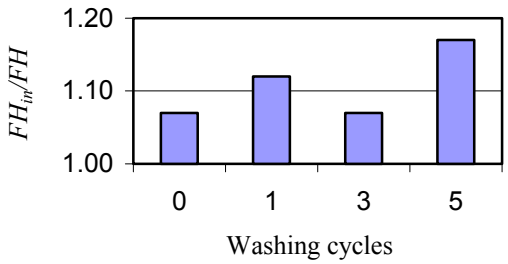

Fig. 4. Relative change of the breaking strength of deknitted *(FH_{in})* and deknitted tumbled *(FH)* yarns after washing

The data from the Table 5 and Fig. 3 indicate the loss of deknitted yarn breaking strength (6.5 – 15.1 %) under all washing cycles after tumbling. The decrease of yarn strength increases with intensification of the washing procedure. Parallel changes indicate the indice of work at maximum force (7.4 – 20.6 %) of tested yarns (Fig. 4). Contrary to the breaking strength the deknitted tumbled yarns showed a greater values of initial elasticity modulus (Fig. 5). The influence of the washing cycles on the

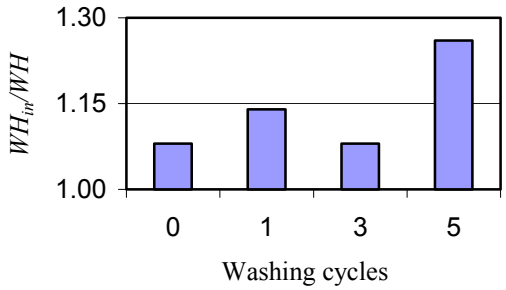

Fig. 5. Relative change of the work at max. force of deknitted (WH_{in}) and deknitted tumbled (WH) yarns after washing

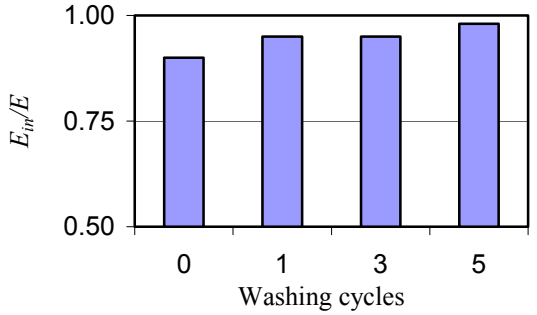

Fig. 6. Relative changes of the initial modulus of deknitted (E_{in}) and deknitted tumbled (E) yarns after washing

character of the changes in the yarn rigidity is also visible.

The data from the Table 5 and Fig. 4, 5 and 6 show that the tumbling process causes deterioration in the tensile properties of the tested yarns as in washed and unwashed states.

CONCLUSIONS

The main conclusions from the experiment performed are as follows:

1. The knitting operation changes the tensile properties of blended yarns to a degree dependent of the stitch density. After knitting tested wool / acrylic and cotton / / acrylic blended yarns lost their breaking strength and initial elasticity modulus in comparison with initial yarns. After knitting the tested yarns became less rigid (wool / / acrylic yarns 9.1 – 15.1 %, cotton / acrylic yarns 7.8 – 11.9 %). The loss of yarn strength increases with intensification of the knitting density.

2. The washing conditions influence on the tensile characteristics of tested blended yarns. After washing the elongation at break of cotton / acrylic yarns decreases in all cases of knitting conditions. After 1st washing cycle blended wool / acrylic and cotton / acrylic yarns became less rigid. Initial elasticity modulus for wool / acrylic yarns decreases from 0.5 till 8.9 % and for cotton / acrylic yarns from 5.0 till 10.7 %. With the increasing of washing cycles both types of the yarns loss the initial elasticity modulus. Washing operation causes more significantly change in the behavior of cotton / acrylic yarns in comparison with these properties of wool / acrylic yarns.

3. The tumbling process in Pilling box tester causes deterioration in the tensile characteristics of tested wool / acrylic yarns as in washed and unwashed states. The experiments show the loss of yarns breaking strength (6.5 – 15.1 %) and work at maximum force (7.4 – 20.6 %) under all washing cycles after tumbling. The deknitted tumbled yarns showed a greater values of initial elasticity modulus. After washing tumbled yarns became less rigid.

4. The results obtained with blended wool / acrylic and cotton / acrylic yarns used in these experiments show some tends which would probably be repeated with other sorts of yarns and other experimental conditions.

REFERENCES

1. **Choi, M.-S., Ashdown, S. P.** Effect of Changes in Knit Structure and Density on the Mechanical and Hand Properties of Weft-Knitted Fabrics for Outwear *Textile Research Journal* 70 (12) 2000: pp. 1033 – 1045.
2. **Tadic, T., Miloslalvljevic, S., Stankovic, S., Tisma, V.** Influence of Knitting Conditions on the Change in Yarn Properties *Knitting technology* 5 1999: pp. 14 – 18.
3. **Mikučionienė, D.** The Change of Cotton Plain Knitted Fabric Shrinkage During its Manufacture *Reports of International Conference „Baltic Textile & Leather"* Kaunas, Technologija, 2003: pp. 95 – 97.
4. **Tvarijonavičienė, B., Šaulytė, I., Laureckienė, G.** The Influence of Washing on Pilling Behaviour of Flat Knitted Fabrics *Reports of International Conference "Baltic Textile & Leather"* Kaunas, Technologija, 2003: pp. 89 – 94.
5. ISO 6330. Textile – Domestic Washing and Drying Procedures for Textile Testing. 2000: 13 p.
6. **Spencer, D. J.** Knitting Technology: a Comprehensive Handbook and Practical Guide. Third Edition. Cambridge, Woodhead Publishing Limited, 2001. ISBN 185573 3331.
7. ISO 2062. Textiles – Yarns from Packages – Determination of Single – end Breaking Force and Elongation at Break. 1995: 8 p.
8. ISO/FDIS 12945-1. Textile – Determination of Fabric Propensity to Surface Fuzzing and to Pilling. Part 1: Pilling Box Method. 2000: 7 p.
9. **Matukonis, A., Palaima, J., Vitkauskas, A.** Textile Materials Science. Vilnius, Mokslas, 1976 (in Lithuanian).