

ASSESSMENT OF THE INFLUENCE OF THE STRUCTURAL, MATERIAL AND PROCESSING PARAMETERS ON THE KNITTED LOOP LENGTH WITH ANOVA

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Abstract

Five different weft knitted structures (two double and three single), made of two materials (polyacrylonitrile-PAN fibres and viscose- VIS), two yarns (conventional and elasticized), in two densities (open and close) and relaxed by two procedures (dry and wet) were systematically explored. Impact of one or more factors on the loop length was studied. The measurement results were analyzed by multifactorial analysis of variance (ANOVA). The main structural parameters – factors – with the greatest impact are: density, knitted structure and relaxation. Important two-factor interactions are: material-yarn, yarn-relaxation and material-relaxation.

The results of the 5×2^4 experiments were separated into two groups according to the yarn structure (conventional and elasticized). They were analyzed by 4-factorial ANOVA. It was established that within each of the two groups, density and fabric structure exhibit greatest impact on the loop length. Relaxation has much larger impact in the case of elasticized yarns than in the case of conventional yarns.

Keywords: weft knitted structures, elasticized yarns, statistical analysis, ANOVA

INTRODUCTION

Many studies have been conducted to analyze the relationship between basic knitted fabric parameters and loop length by using statistical methods. The dimensional properties of cotton/spandex single jersey were investigated and the results compared to fabrics knitted from cotton alone [1]. The impact of one or more factors on loop length was studied for single jersey made from conventional and elasticized yarn [2]. The tightness factor and the dimensional properties of cotton/spandex knitted fabrics have also been investigated [3]. In the study of fashioned knitted fabrics [4], the factors that are essential for achieving the planned dimensions of the knitted fabric were analyzed and assessed through inquiry of the leading experts opinion in the knitting industry by the method of the rank correlation. Geometrical properties of knitted fabrics, made from conventional yarns and those incorporating elastane core-spun yarns, differ considerably. Addition of elastane improves most properties of weft knitted fabrics: extensibility, elasticity

and adaptability to a body shape wearing knitted fabric. In the same way, elastane has a significant effect on knitted fabrics' dimensional properties. By incorporating elastane into the structure, knitted products have become useful for special purposes, needing exemplary comfort and stretch properties (eg. sportswear, compressing underwear, etc.) and also into non-clothing areas of use (eg. medicine, upholstery, automotive textiles, etc.).

Knitting with elastane core-spun yarns results in a compact, or very compact structure because of the yarn extension in the knitting zone, fabric relaxation in unloaded state after relaxation and yarn compression within the knitted structure. This results in knitted loop geometry changes and consequently in changes to knitted fabric structural parameters. These depend on numerous factors, eg. material composition, yarn structure, knitted fabric structure, knitting process, after-treatment, relaxation level and others.

The purpose of this investigation was to study the influence of material, structural and

process parameters of knitted fabrics on the loop length.

EXPOSITION

Sample preparation

For the study of the structural parameters of single and double weft knitted fabrics, basic structures were selected. Single structures were composed of knitted loops, tucks and floats: single miss structure – labelled M, single half cardigan – labelled PF and single full cardigan – labelled F. Considering double structures, basic structures comprised exclusively of knitted loops were selected: 1x1 purl structure – labelled LL, and 1x1 rib structure – labelled RR.

For the preparation of knitted samples, ring spun yarns made from two types of fibres were used, namely viscose (sample labelling – VIS) and polyacrylonitrile fibres (sample labelling PAN). From each raw material, elastane core yarns were custom-made to order, under the same processing and environment conditions (samples labelled – ELAS), displaying the same linear density and material composition: 97.8% CV/2.2% EL and 97.8% PAN/2.2% EL, respectively. For comparison, two ring-spun yarns without elastane (samples labelled CONV), were made from the same 100% viscose fibres and 100% polyacrylonitrile fibres, showing the same nominal linear density as the elastane core-spun yarns. The linear density of all yarns was 100 tex. The yarn twist was 221Z for conventional yarns without elastane and 281Z for elastane core-spun yarns. The knitted samples were produced on the electronic flat weft knitting machine STOLL CNCA, gauge E8. All samples were knitted with an equal yarn input tension, equal knitted fabric take-off and in identical environment conditions. The knitted samples were produced in two couliering depths in order to prepare more open (sample labelling – OPEN) and a more close structure (sample labelling – CLOSE). To enable a comparison of results, investigated samples needed to be in the reference state. One-phase and two-phase procedures for the relaxation of the investigated knitted fabrics were designed. A dry static relaxation (samples labelling DR) was one-phase: knitted samples were placed unloaded to the standard environment for 72 hours. A two-phase knitted fabric consolidation was executed first by dry relaxation (as described)

and further by dynamic wet relaxation (samples labelling WR), ie. with laundering at 30°C followed by short spinning, 40-min drying, four cycles of short rinsing and 40-min tumble drying, and placing wet-relaxed samples flat to the standard environment, for at least 24 hours, after drying was finished. For the yarn parameters measurements, the yarns were dry and wet relaxed as well. A total of 80 samples of weft knitted structures were prepared specially for the study (Table 1).

Table.1 Independent variables

Factors X_i	X_1	material	PAN
			VIS
	X_2	yarn	CONVentional
			ELASticized
	X_3	structure	RR (1x1 Rib)
			LL (1x1 Purl)
			M (Miss single)
			PF (Perlfang single)
			F (Fang single)
	X_4	density	OPEN
			CLOSE
	X_5	relaxation	Dry Relaxation
			Wet Relaxation

Influence of the structural, material and process parameters on the loop length

The experimental results were statistically processed by the ANOVA, first on the basis of the 5×2^4 factorial design and then on the basis of the 5×2^3 factorial design. The impact of the process and the structural parameters of knitted fabrics and also of their interactions on the basic parameter of the knitted fabric – the loop length, was evaluated.

In the investigation of the structural parameters of the knitted fabrics with incorporated elastane, the independent variables, ie. factors, were as follows: knitted fabric density, relaxation method, yarn structure, fibre type and knitted structure type. Each factor may have two or more values, or levels, as stated hereafter. The dependent variable – response – was the loop length. The parameters, showing in Table.1, (defined either on two or five levels) were monitored. Firstly, all the samples were treated as a whole ($5 \times 2^4 = 80$ experiments). Multifactorial ANOVA showed that the investigated system is rather complex, since in addition to the main effects and the two-factorial interactions, some higher-order (three- and four-) interactions were found

to be marginally statistically significant. If we are to focus only on the main effects and two-factorial interactions (Table 2), it can be seen that the most important factors are: density

(X_4), structure (X_3) and relaxation (X_5). Considering the interactions, the most important are: material-yarn (X_1X_2), yarn-relaxation (X_2X_5) and material-relaxation (X_1X_5).

Table 2. Influence of structural, material and process parameters on loop length – 5-factorial design for all samples (main effects and two-factorial interactions)

All samples	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X_1 : material	0.731239	1	0.731239	9.97	0.0016
X_2 : yarn	0.0516994	1	0.0516994	0.70	0.4012
X_3 : structure	1109.44	4	277.36	3780.74	0.0000
X_4 : density	1174.72	1	1174.72	16012.72	0.0000
X_5 : relaxation	17.9659	1	17.9659	244.90	0.0000
INTERACTIONS					
X_1X_2 : material - yarn	16.6393	1	16.6393	226.81	0.0000
X_1X_3 : material - structure	1.98854	4	0.497135	6.78	0.0000
X_1X_4 : material - density	0.221253	1	0.221253	3.02	0.0824
X_1X_5 : material - relaxation	11.752	1	11.752	160.19	0.0000
X_2X_3 : yarn - structure	1.98977	4	0.497444	6.78	0.0000
X_2X_4 : yarn - density	5.17619	1	5.17619	70.56	0.0000
X_2X_5 : yarn - relaxation	13.804	1	13.804	188.16	0.0000
X_3X_4 : structure - density	37.5724	4	9.3931	128.04	0.0000
X_3X_5 : structure - relaxation	4.42334	4	1.10584	15.07	0.0000
X_4X_5 : density - relaxation	7.35698	1	7.35698	100.28	0.0000
residual	115.104	1569	0.0733614		
total (corrected)	2518.93	1599			

Table 3. Influence of structural, material and process parameters on loop length – 4-factorial design for the group of conventional yarns without elastane (main effects and two-factorial interactions)

Conventional yarns without elastane (CONV)	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X_1 : material	12.1734	1	12.1734	205.63	0.0000
X_3 : structure	551.086	4	137.771	2327.16	0.0000
X_4 : density	667.924	1	667.924	11282.22	0.0000
X_5 : relaxation	0.136895	1	0.136895	2.31	0.1283
INTERACTIONS					
X_1X_3 : material - structure	5.89779	4	1.47445	24.91	0.0000
X_1X_4 : material - density	0.616328	1	0.616328	10.41	0.0013
X_1X_5 : material - relaxation	0.677157	1	0.677157	11.44	0.0007
X_3X_4 : structure - density	28.0961	4	7.02402	118.65	0.0000
X_3X_5 : structure - relaxation	7.86683	4	1.96671	33.22	0.0000
X_4X_5 : density - relaxation	3.75038	1	3.75038	63.35	0.0000
residual	45.9995	777	0.0592015		
total (corrected)	1324.22	799			

Next, the measurements were divided into two groups with 40 experiments each, separated according to the yarn structure (CONV or ELAS) and processed by 4-factorial ($2 \times 2 \times 2 \times 5$) ANOVA (Tables 3 and 4). Analysis of the main effects showed that density (X_4) and structure (X_3) have the greatest impact on the loop length for both

groups. It should be noted that the relaxation (X_5) has much greater impact for knitted fabrics with incorporated elastane, than for conventional knitted fabrics, where this impact is negligible. Furthermore, the interaction material-relaxation (X_1X_5) is very important with knitted fabrics with incorporated elastane.

Table 4. Influence of structural, material and process parameters on loop length – 4-factorial design for the group of elastane core-spun yarns (main effects and two-factorial interactions)

Elastane core-spun yarns (ELAST)	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X ₁ : material	5.19709	1	5.19709	122.19	0.0000
X ₃ : structure	560.345	4	140.086	3293.68	0.0000
X ₄ : density	511.968	1	511.968	12037.28	0.0000
X ₅ : relaxation	31.6331	1	31.6331	743.75	0.0000
INTERACTIONS					
X ₁ X ₃ : material - structure	0.6406	4	0.16015	3.77	0.0048
X ₁ X ₄ : material - density	2.1033	1	2.1033	49.45	0.0000
X ₁ X ₅ : material - relaxation	32.1602	1	32.1602	756.14	0.0000
X ₃ X ₄ : structure - density	12.3619	4	3.09047	72.66	0.0000
X ₃ X ₅ : structure - relaxation	1.59399	4	0.398496	9.37	0.0000
X ₄ X ₅ : density - relaxation	3.6073	1	3.6073	84.81	0.0000
residual	33.0473	777	0.0425319		
total (corrected)	1194.66	799			

Table 5. Influence of structural, material and process parameters on loop length – 4-factorial design for the double 1x1 rib structure (main effects and two-factorial interactions)

Double 1x1 rib structures (RR)	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X ₁ : material	0.49298	1	0.49298	9.05	0.0028
X ₂ : yarn	0.0285013	1	0.02850	0.52	0.4699
X ₄ : density	134.292	1	134.292	2466.32	0.0000
X ₅ : relaxation	6.26081	1	6.26081	114.98	0.0000
INTERACTIONS					
X ₁ X ₂ : material - yarn	8.33986	1	8.33986	153.16	0.0000
X ₁ X ₄ : material - density	0.0485113	1	0.04851	0.89	0.3460
X ₁ X ₅ : material - relaxation	8.51513	1	8.51513	156.38	0.0000
X ₂ X ₄ : yarn - density	0.27378	1	0.27378	5.03	0.0256
X ₂ X ₅ : yarn - relaxation	1.43916	1	1.43916	26.43	0.0000
X ₄ X ₅ : density - relaxation	1.797	1	1.797	33.00	0.0000
residual	16.8251	309	0.05445		
total (corrected)	178.312	319			

Table 6. Influence of structural, material and process parameters on loop length – 4-factorial design for the double 1x1 purl structure (main effects and two-factorial interactions)

Double 1x1 purl structures (LL)	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X ₁ : material	0.202005	1	0.202005	2.31	0.1297
X ₂ : yarn	0.351125	1	0.351125	4.01	0.0460
X ₄ : density	272.728	1	272.728	3116.87	0.0000
X ₅ : relaxation	7.2	1	7.2	82.29	0.0000
INTERACTIONS					
X ₁ X ₂ : material - yarn	0.272611	1	0.272611	3.12	0.0785
X ₁ X ₄ : material - density	0.447005	1	0.447005	5.11	0.0245
X ₁ X ₅ : material - relaxation	4.98501	1	4.98501	56.97	0.0000
X ₂ X ₄ : yarn - density	0.372645	1	0.372645	4.26	0.0399
X ₂ X ₅ : yarn - relaxation	2.50986	1	2.50986	28.68	0.0000
X ₄ X ₅ : density - relaxation	0.688205	1	0.688205	7.87	0.0054
residual	27.0377	309	0.08750		
total (corrected)	316.794	319			

Table 7. Influence of structural, material and process parameters on loop length – 4-factorial design for the single miss structure (main effects and two-factorial interactions)

Single miss structures (M)	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X ₁ : material	0.089445	1	0.089445	9.15	0.0027
X ₂ : yarn	0.049005	1	0.049005	5.02	0.0258
X ₄ : density	161.099	1	161.099	16488.21	0.0000
X ₅ : relaxation	2.8823	1	2.8823	295.00	0.0000
INTERACTIONS					
X ₁ X ₂ : material - yarn	1.20295	1	1.20295	123.12	0.0000
X ₁ X ₄ : material - density	1.24127	1	1.24127	127.04	0.0000
X ₁ X ₅ : material - relaxation	1.54985	1	1.54985	158.62	0.0000
X ₂ X ₄ : yarn - density	0.25088	1	0.25088	25.68	0.0000
X ₂ X ₅ : yarn - relaxation	0.128	1	0.128	13.10	0.0003
X ₄ X ₅ : density - relaxation	0.206553	1	0.206553	21.14	0.0000
residual	3.0191	309	0.009771		
total (corrected)	171.718	319			

Table 8. Influence of structural, material and process parameters on loop length – 4-factorial design for the single half cardigan structure (main effects and two-factorial interactions)

Single half cardigan structures (PF)	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X ₁ : material	0.000928	1	0.000928	0.05	0.8227
X ₂ : yarn	0.684038	1	0.684038	37.08	0.0000
X ₄ : density	288.297	1	288.297	15627.55	0.0000
X ₅ : relaxation	6.02665	1	6.02665	326.68	0.0000
INTERACTIONS					
X ₁ X ₂ : material - yarn	2.90417	1	2.90417	157.42	0.0000
X ₁ X ₄ : material - density	0.148997	1	0.148997	8.08	0.0048
X ₁ X ₅ : material - relaxation	2.90227	1	2.90227	157.32	0.0000
X ₂ X ₄ : yarn - density	0.903656	1	0.903656	48.98	0.0000
X ₂ X ₅ : yarn - relaxation	3.02934	1	3.02934	164.21	0.0000
X ₄ X ₅ : density - relaxation	1.60815	1	1.60815	87.17	0.0000
residual	5.70042	309	0.018448		
total (corrected)	312.205	319			

Table 9. Influence of structural, material and process parameters on loop length – 4-factorial design for the single cardigan structure (main effects and two-factorial interactions)

Single cardigan structures (F)	SS	Df	MS	F-ratio	P-value
MAIN EFFECTS					
X ₁ : material	1.93442	1	1.93442	15.51	0.0001
X ₂ : yarn	0.928805	1	0.92881	7.45	0.0067
X ₄ : density	355.873	1	355.873	2852.82	0.0000
X ₅ : relaxation	0.0195313	1	0.01953	0.16	0.6926
INTERACTIONS					
X ₁ X ₂ : material - yarn	8.46951	1	8.46951	67.90	0.0000
X ₁ X ₄ : material - density	1.78802	1	1.78802	14.33	0.0002
X ₁ X ₅ : material - relaxation	0.18818	1	0.18818	1.51	0.2203
X ₂ X ₄ : yarn - density	6.26081	1	6.26081	50.19	0.0000
X ₂ X ₅ : yarn - relaxation	11.7351	1	11.7351	94.07	0.0000
X ₄ X ₅ : density - relaxation	4.71906	1	4.71906	37.83	0.0000
residual	38.5459	309	0.12474		
total (corrected)	430.462	319			

Finally, the measurement results were split into 5 groups each containing 16 experiments, with regard to the knitted structure. Each group was processed by 4-factorial (2x2x2x2) ANOVA. The magnitude of effects can be deduced from Tables 5-9. Density (X_4) has by far the greatest impact for all the knitted structures. As far as factors are concerned, we see that relaxation (X_5) is also important for all structures, except for the single knitted structure – full cardigan (F).

Graphical representation of the results

In Fig.1 the ordinate (y) denotes the average loop length (L), and the abscissa (x) denotes different knitted structures. It can be seen clearly that the loop length depends on the knitted structure. The loop length (L) of the close and open structure, respectively is shown in Fig.2 The ordinate (y) denotes the average loop length (L), and the abscissa (x) denotes different densities. The density resulting from the couliering depth adjustment has a very strong impact on the loop length.

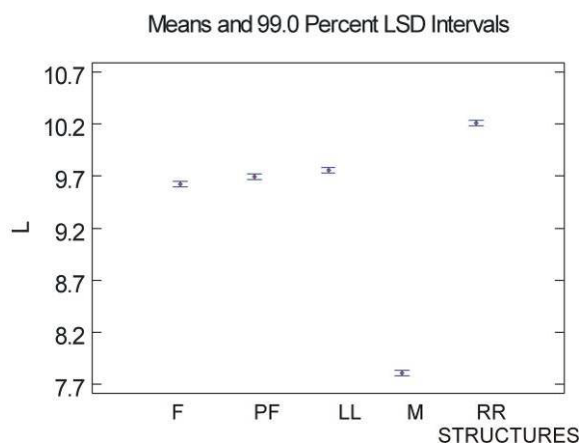


Fig. 1. Loop length for different knitted structures: single full cardigan, single half cardigan, single miss, 1x1 rib and 1x1 purl

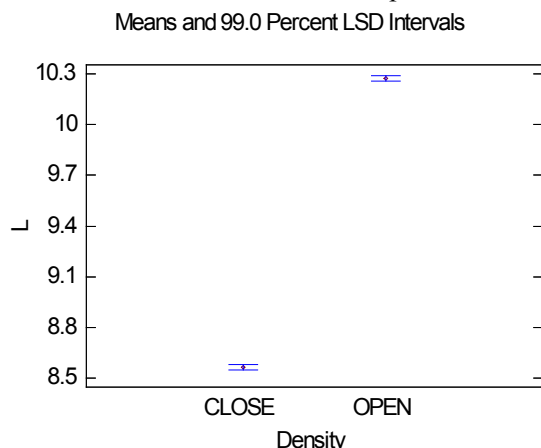


Fig. 2. Loop length for structures, knitted with different densities: close and open

The loop length (L) after dry and wet relaxation is shown in Fig.3. The ordinate (y) denotes the average loop length (L), and the abscissa (x) denotes different relaxation methods (DR and WR). Average loop length after dry (DR) and wet (WR) relaxation varies in a big interval. The loop length is reduced after wet relaxation.

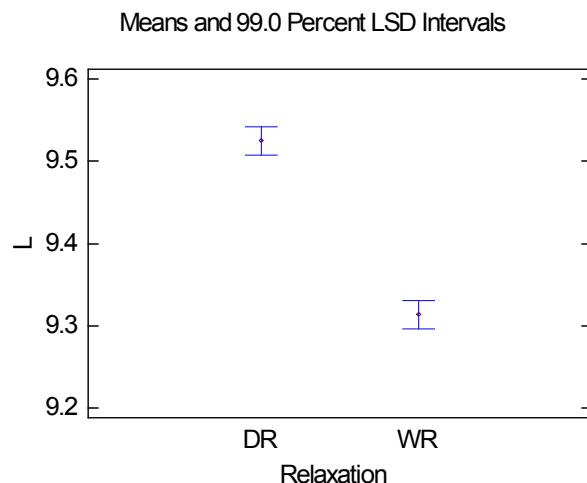


Fig. 3. Loop length after dry (DR) and wet (WR) relaxation

The interaction material-yarn and its impact on the loop length is shown in Fig.4. In the case of the conventional yarns, the loop length is higher for the knitted fabrics made from polyacrylonitrile while for the elasticized yarns, the loop length is higher for the knitted fabrics made of viscose.

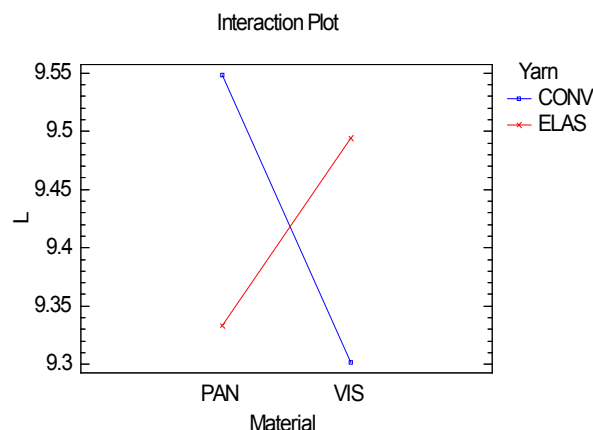


Fig. 4. Loop length of knitted fabrics made from conventional and elasticized yarns composed of PAN and viscose fibers

The interaction material-relaxation and its impact on the loop length is shown in Fig.5. In the case of the wet relaxed knitted fabrics, the loop length is higher for the knitted fabrics made from polyacrylonitrile while for the dry

relaxed knitted fabrics, the loop length is higher for the knitted fabrics made of viscose.

The interaction yarn-relaxation and its impact on the loop length is shown in Fig. 6. In the case of the wet relaxed knitted fabrics, the loop length is higher for the knitted fabrics made from conventional yarns while for the dry relaxed knitted fabrics, the loop length is higher for the knitted fabrics made from elasticized yarns.

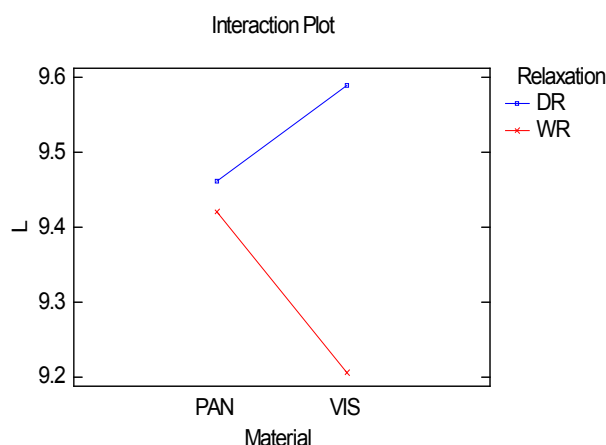


Fig. 5. Loop length of dry and wet relaxed knitted fabrics made from PAN and viscose yarns

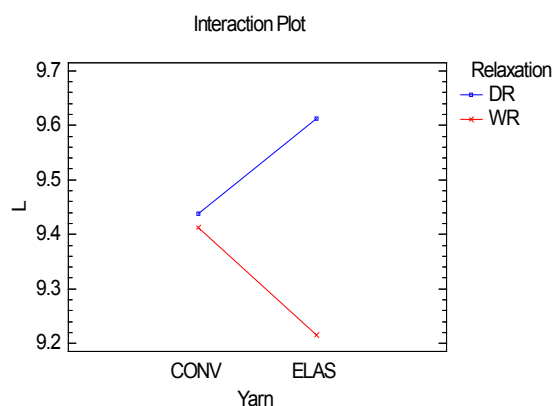


Fig. 6. Loop length of dry and wet relaxed knitted fabrics made from conventional and elasticized yarns

CONCLUSION

Knitted loop geometry is a very complex system. Fibre type, yarn structure, knitted structure, knitted fabric density level and relaxation method influence the loop length. The most important influences are: density level, knitted structure and relaxation method, and also interactions fibre type – yarn structure, yarn structure – relaxation method and fibre type – relaxation method.

The relaxation method has much greater impact on loop length for the knitted fabrics with incorporated elastane than for the conventional knitted fabrics, where this impact is negligible. Furthermore, the interaction fibre type-relaxation method is very important with knitted fabrics incorporating elastane. Knitted fabric density level has by far the greatest impact on the loop length for all knitted structures. The relaxation method is also very significant for all structures, except for that of the single full cardigan.

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