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Investigation into Fabric Spirality in Various Knitted Fabrics and Its Effect on Efficiency in Apparel Manufacturing

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Abstract

The present study aimed to comparatively determine fabric spirality in single jersey knitted fabrics manufactured from different fibers and fiber blends under the same conditions as well as its effect on the efficiency of apparel manufacturing. To that end, the fabric spirality was studied for 18 different fabrics manufactured from nine different fiber blends (100% Organic Cotton, 100% Cotton, 100% Viscose, 100% Modal, 95% Viscose-5% PES, 50% Cotton-50% Viscose, 50% Modal-50% Organic Cotton, 70% Viscose-30% PES, 80% Viscose-20% PES) at 2 different knitting densities. In order to determine the effect of fabric spirality on the marker plan, a t-shirt model was selected and a total of 8 different fabric marker plans were prepared in 2 different assortments and at 3 different spirality rates. Finally fabric efficiency and the effect of spirality on unit fabric consumption were investigated for all fabric marker plans. In the end, the greatest spirality was observed for 100% viscose fabrics. It was also determined that as the fabric spirality increases (5%, 7% and 10%), CAD efficiency decreases by rates of 2.4%, 3.68% and 5.25%, respectively, in comparison with the marker plan for the fabric not exhibiting spirality.

Key words: *viscose knitted fabric, loop length, fabric spirality, garment manufacturing, CAD productivity.*

Introduction

Fabric spirality is considered as one of the most prominent factors effecting the visual quality of knitted fabrics. Especially it is frequently observed in single jersey fabrics manufactured from regenerate cellulose fibers. The spirality problem is that when we knit a rectangular piece of fabric, it leans towards one side and becomes a parallelogram. The wales are no longer at right angles with the courses [1]. If the distortion exceeds 5°, it is considered an important problem [2]. Single jersey fabric spirality is the most important issue which creates big problems at the clothing step. T-shirt production, for example, suffers from many quality problems linked to fabric spirality, such as mismatched patterns, sewing difficulties, displacement of the side seam to the back and front of the body, and garment distortion [3-5]. Spirality or distortion in the wale lines not only influences fabric aesthetics but also decreases the fabric utilisation yield during the cutting process, leading to an increase in the material cost.

There are many researches concerning spirality. Researchers classified fabric spirality into four main categories: fiber and yarn causes within the frameworks of material causes and knitting causes, and finishing causes within the framework of process causes [4, 5]. Fiber causes include the fiber type, fiber quality, fiber torsional rigidity, fiber flexural rigidity, fiber blend, fiber finess, and fiber length. Yarn causes include the yarn voluminosity, yarn spinning process, fiber arrangement, twist level, twist direction, yarn linear density, yarn plying, yarn preconditioning and mechanical properties [4]. The main factor for spirality is the yarn twist-liveliness, denoting the active torsional energy present in the yarn [6]. Knitting causes include the fabric density, tightness factor, loop length, fabric structure, knitting machine gauge, needle type, number of feeders, yarn input tension, fabric take-down tension, etc. Finishing causes include stentering, calandering, soft ner, mercerising, resins and enzymes [4].

Coruh and Celik investigated the effects of fabric density and nozzle type on the structural properties and spirality of single jersey knitted fabrics. They explained that the effect of nozzle type on spirality is found statistically insignificant, whereas that of the yarn loop length is significant [7]. Degirmenci and Topalbekiroğlu observed in their study that the fabric weight per m² has a significant effect on spirality for all yarn types [8]. Kirecci et al. indicated that the spirality values of plied yarn fabrics are slightly lower than those of sirospun yarn fabrics at finer yarn count values [9]. Hannan et. al explained in their study that an increment in the stitch length of fabrics results in an increase in spirality and a decrement in GSM. The weight per unit area and thickness of the fabrics are higher, but the spirality is lower [10]. Xu et. al carried out an evaluation of the physical performance of 100% cotton knitted fabrics and garments produced with a modified low twist and conventional ring yarns during actual wearing and in washing trials. Experimental results showed that the properties of side seam displacement, fabric spirality, dimensional stability and skewness change in T-shirts and sweaters made from modified single yarns are comparable to those of garments produced from control plied yarns but much improved when compared to those from the control single yarns [11].

Researchers employed ANN, regression models, mathematical formulation, genetic programming and image analysis methods to estimate the fabric spirality problem that may arise during manufacturing. Various estimation parameters were described and successful estimation results reported in studies [12-16].

Table 1. Knitting machine production parameters.

Machine diameter, inch (cm)	32 (81.28)
Machine fineness, gauge	28
Number of systems	96
Machine speed, rev/min	24
Total number of needles on the machine	2760
Feed type	Positive

In the present study, by considering the fiber types most frequently used and preferred in apparel manufacturing, fabric spirality values were investigated for fabrics manufactures under the same conditions. The effect of the spirality of the fabrics manufactured on unit apparel fabric consumption and CAD efficiency was studied. This research will be helpful particularly for knitwear companies and designers who deal with compact spun yarn knitted fabric and garments, as before starting manufacturing in a factory, the spirality angle of single cotton jersey fabrics and garments can be easily predicted using the factors defined.

Material and method

Yarn and fabric properties

Spirality has fiber, yarn, knitted and finishing causes, but in the first part of the study, the effect of fiber type and fabric density on fabric spirality was investigated. The values of spirality for single jersey fabrics knitted from different yarns produced with the same yarn numbers and machine settings were evaluated. A Keumyong (KM-3WV4T) type circular knitting machine of 28 gauge and 32 inch (81,28 cm) diameter with positive feeding systems was used for fabric production. All machine settings were kept exactly the same during the knitting process. Knitting machine production parameters are given in ***Table 1***.

The control parameters were selected as follows: yarns of type most commonly used in textile industry were produced from nine different fibers and fiber blends. Two different *fabric density* values were obtained by adjusting the yarn loop length for 100 needles. (Two levels of loop length were selected: high density -0.27 cm and low density -0.32 cm).

In total, 18 different fabrics were manufactured from nine different fibers and fiber blends (100% Organic cotton, 100% Cotton, 100% Viscose, 100% Modal, 95% Viscose-5% PES, 50% Cotton-50% Viscose, 50% Modal-50% Organic cotton, 70% Viscose-30% PES, 80% Viscose-20% PES) in two different knitting densities. All the fabrics were knitted as single jersey with Ne 30/1 yarns. The yarns used were produced at nearly closed machine settings. All the yarns were manufactured as ring yarn with the same twist multiplier (αe = 3.6). Furthermore all the yarns were twisted in the Z direction with the conventional ring spinning method. The staple length of PES and viscose fibres was 38 mm. ***Table 2*** exhibits characteristics of the fabrics manufactured.

Table 2. Fabric characteristics

Yarn type	Sample No.	Fabric classificaiton for loop length, fabric density	Loop length adjusted on machine (100 Needle), cm
100% Organic cotton	N1	High	27
	N2	Low	32
100% Viscose	N3	High	27
	N4	Low	32
100% Modal	N5	High	27
	N6	Low	32
100% Cotton	N7	High	27
	N8	Low	32
50% Cotton 50% Viscose	N9	High	27
	N10	Low	32
50% Modal 50% Organic cotton	N11	High	27
	N12	Low	32
95% Viscose 5% PES	N13	High	27
	N14	Low	32
80% Viscose 20% PES	N15	High	27
	N16	Low	32
70% Viscose 30% PES	N17	High	27
	N18	Low	32

Physical fabric property testing

- Course and wale density values per cm were determined according to Standard EN 14971 [17].
- Yarn loop length was determined for 100 needles in accordance with Standard EN 14970 [18]. Stitch density is the number of loops per unit area, which can be obtained by multiplying the number of wales and courses per unit length (ASTM D 3887) [19];

Stitch density in sq. cm =
= wales per cm x courses per cm. (2)

- Dimensional properties of the plain knitted fabrics were determined by calculating the dimensional constants (K values- *Kc, Kw* and *Kr*), which were introduced by Doyle and Munden [20-21], and are given below:

$$K_c = cpc \ x \ l \quad (3)$$

$$K_w = wpc \ x \ l \quad (4)$$

$$K_r = K_c / Kw \quad (5)$$

Where, *cpc* is the course density, *wpc* the wale density, and *l* the loop length.

- Generally the tightness factor of the knitted fabric is given [21] as follows:

$$\text{Tightness factor} = \sqrt{tex}/l \quad (6)$$

- The weight of 100 cm^2 fabric specimens prepared with a sample cutter was established using a sensitive scale. This measurement was repeated for five different areas of fabrics, and their average was taken into consideration [22].

Measuring of fabric spirality

The fabric samples were conditioned for 48 hours before testing at standard relative humidity of 65%±2% and 20±2 °C temperature for dry relaxed fabrics in accordance with the standard EN ISO 139 [23]. For spirality investigation, two fabric samples of 30 cm × 30 cm dimensions were taken, stitched on three sides with one side open. The samples were laundered according to the AATCC Test Method 179 (2012) [24]. The washing machine preferred was of the domestic type. The washing process lasted 2 hours and 15 minutes at a temperature of 60 °C. Then the samples were dried on a line. After that they were fully conditioned for 48 hours in a standard atmosphere of 20±2 °C temperature and 65±2% relative humidity. Then those samples were tested to measure the dimensional stability and shrinkage and spirality percentage by the ISO:16322 (2013) method [25]. Five measurements were performed for each fabric sample.

Then the spirality of the fabric was measured using formula (1) below:

$$\text{Spirality \%} = 100 * B/A \qquad (1)$$

Where, B = displacement of the side seam at the bottom after washing (shown in ***Figure 1***), A= side seam length.

Preparing garment laying plan

For determining the effect of fabric spisrality on the fabric spread process, the t-shirt model in ***Figure 2*** was selected, and 8 different fabric marker plans for 2 different assortments (6 and 12) in XXS, XS, S, M, L & XL sizes were prepared using 3 different spirality rates (5%, 7% and 10%). These spirality ratios were selected because at spirality rates below 5%, manual precautions are carried out while placing the marker on the spread, and spirality ratios over 10% are not common for

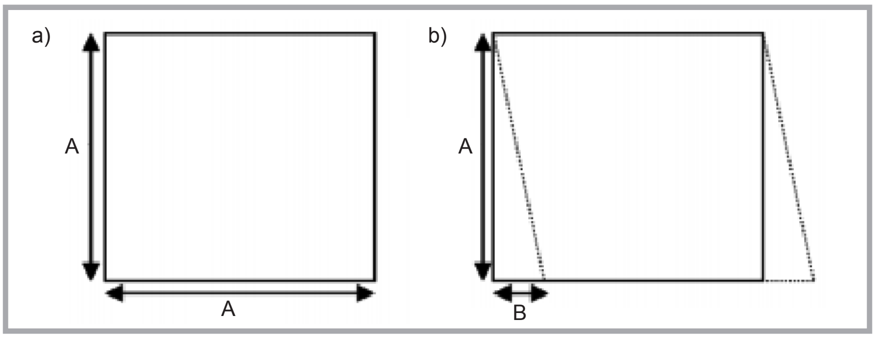
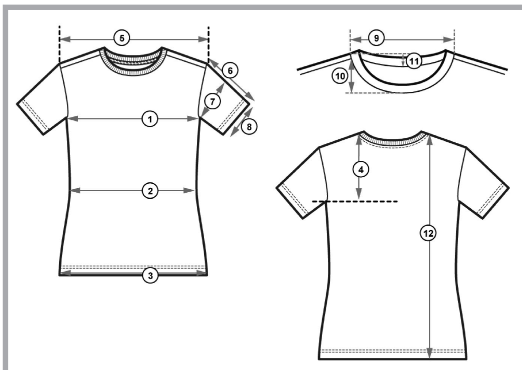


Figure 1. *a) Before washing sample, b) after washing sample [26].*

Table 3. *Marker plans for all size breakdowns.*

Marker No.	Spirality of fabric, %	Size breakdown (Assortment)	Sizes
1	0	6 sizes: 1	1 (XXS, XS, S, M, L , XL)
2		12 sizes: 2	2 (XXS, XS, S, M, L , XL)
3	5	6 sizes: 1	1 (XXS, XS, S, M, L , XL)
4		12 sizes: 2	2 (XXS, XS, S, M, L , XL)
5	7	6 sizes: 1	1 (XXS, XS, S, M, L , XL)
6		12 sizes: 2	2 (XXS, XS, S, M, L , XL)
7	10	6 sizes: 1	1 (XXS, XS, S, M, L , XL)
8		12 sizes: 2	2 (XXS, XS, S, M, L , XL)



* = rev. m-ment	XXS	XS	S	M	L	XL
QC 1 ½ CHEST	38.5	40.5	44.5	48.5	52.5	54.5
2 ½ WAIST	37	39	43	47	51	53
QC 3 ½ BOTTOM	41.5	43.5	47.5	51.5	55.5	57.5
QC 4 SCYE DEPTH fr isp	22	22.5	23.5	24.5	25.5	26
QC 5 SHOULDER TO SHOULDER at fold	36	37	39	41	43	44
QC 6 SLEEVE LENGTH	15.5	15.5	16	17	18	18.5
7 ½ BICEPS	15.5	16	17	18.3	19.6	20.25
8 ½ SLEEVE OPENING	13.5	14	15	16.3	17.6	18.25
QC 9 NECK WIDTH at fold	18.8	19.2	20	20.8	21.6	22
10 NECK DROP FRONT	8.9	9.1	9.5	9.9	10.3	10.5
11 NECK DROP BACK fr isp	2.7	2.8	3	3.2	3.4	3.5
QC 12 LENGTH fr isp	55.9	56.6	58	59.4	60.8	61.5
QC 13 ½ MINIMUM EXTENDED NECKLINE	29	29	29	30.5	32	32.75

Figure 2. *T-shirt model and measurements.*

Table 4. *Physical property test results of fabrics.*

Fabric type	Sample no.	Courses	Wales	Stitch density per cm²	Actual loop lenght, cm	Kc	Kw	Ks = Kc*Kw	Tightness factor = √tex /l	Loop shape factor = Kc/Kw	Mass per unit area, g/m²
		per cm	per cm								
100% Viscose	N1	22.7	12.1	274.67	0.268	6.08	3.24	19.73	16.27	1.88	149
	N2	16	12.2	195.20	0.318	5.09	3.88	19.74	13.71	1.31	141
100% Modal	N3	21	12	252.00	0.267	5.61	3.20	17.96	16.33	1.75	158
	N4	16.2	12	194.40	0.34	5.51	4.08	22.47	12.82	1.35	151
100% Cotton	N5	20.4	12.3	250.92	0.261	5.32	3.21	17.09	16.70	1.66	147
	N6	14	11.3	158.20	0.32	4.48	3.62	16.20	13.63	1.24	141
100% Organic cotton	N7	20.1	11.9	239.19	0.261	5.25	3.11	16.29	16.70	1.69	137
	N8	15.5	11.1	172.05	0.318	4.93	3.53	17.40	13.71	1.40	137
95% Viscose 5% PES	N9	21.6	12.2	263.52	0.268	5.79	3.27	18.93	16.27	1.77	151
	N10	16	11.2	179.20	0.32	5.12	3.58	18.35	13.63	1.43	141
50% Cotton 50% Viscose	N11	22	12	264.00	0.268	5.90	3.22	18.96	16.27	1.83	147
	N12	14.4	11	158.40	0.309	4.45	3.40	15.12	14.11	1.31	147
50% Modal 50% Organic cotton	N13	21	12	252.00	0.265	5.57	3.18	17.70	16.45	1.75	138
	N14	13.8	11.2	154.56	0.314	4.33	3.52	15.24	13.89	1.23	133
80% Viscose 20% PES	N15	20.3	12.2	247.66	0.244	4.95	2.98	14.74	17.87	1.66	158
	N16	16.7	11.5	192.05	0.315	5.26	3.62	19.06	13.84	1.45	141
70% Viscose 30% PES	N17	20.1	11.9	239.19	0.267	5.37	3.18	17.05	16.33	1.69	157
	N18	16	11.1	177.60	0.32	5.12	3.55	18.19	13.63	1.44	139

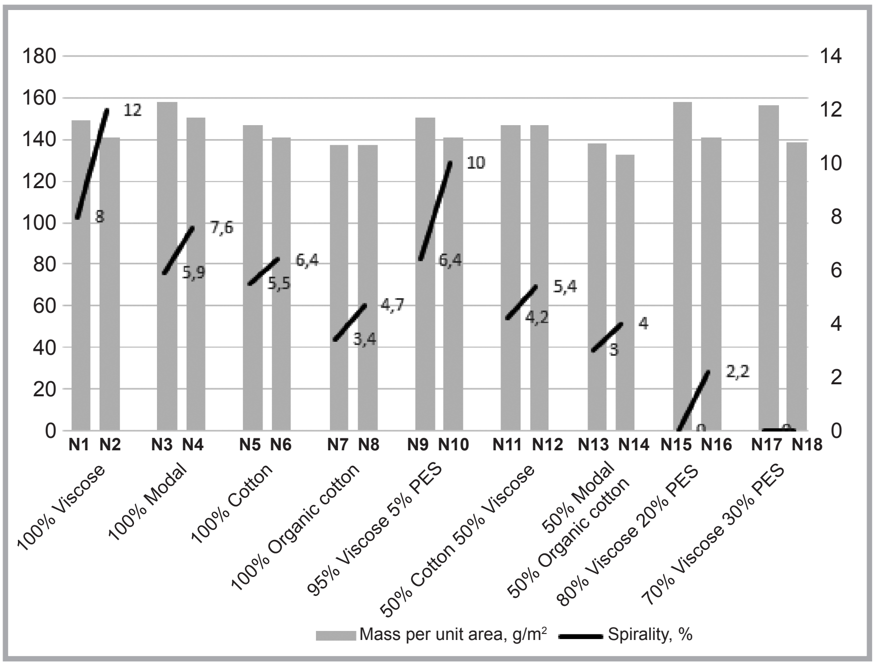


Figure 3. *Fabric spirality % and fabric weight (mass per unit area-g/m²) for all fabrics.*

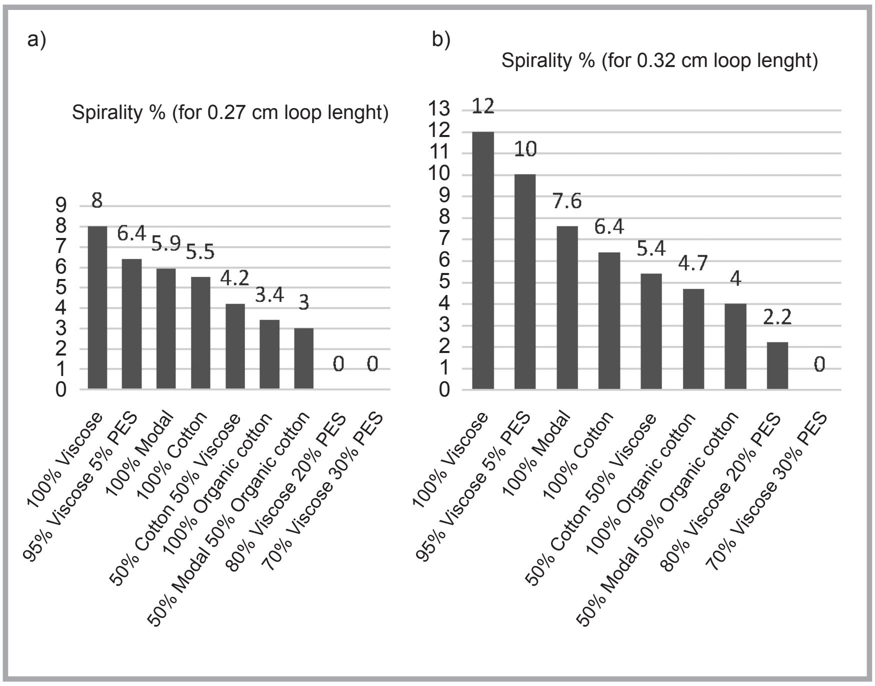


Figure 4. *Fabric spirality (%) for a) 0.27 cm loop length and b) 0.32 cm loop length.*

the fabrics studied. ***Table 3*** exhibits fabric marker details. Fabric efficiency and unit fabric consumption were investigated for all fabric marker plans with respect to different fabric spirality rates.

Statistical analysis

In order to understand the statistical importance of the fiber type and fabric density effect on spirality, a one-way ANOVA was performed. For this aim, the statistical software package SPSS 13.0 was used to interpret the experimental data. All test results were assessed at significance levels $p \leq 0.05$ and $p \leq 0.01$.

Results and discussion

Table 4 exhibits the course density, wale density, stitch density, calculated loop length, tightness factor, loop shape factor and fabric weight (g/m²) results of 18 different fabrics manufactured in a single jersey knitted fabric form in two different fabric densities from 9 different fibers and fiber blends. as mentioned previously.

As can be seen from ***Table 4***, since the wale count per cm usually depends on the machine settings, the wale count per cm values in all fabrics ranged between 11-12.3 for the two different fabric densities. Course count values showed higher variation in the two different density values of all fabrics compared to the wale count. According to ***Table 4***, for all fiber types, the course count per cm values were higher in the high density (0.27 cm loop lenght) fabrics than in the low density (0.32 cm loop length) fabrics. Similar findings were obtained by Tao et al. [27] and Hassan [28]. The loop length expresses the tightness of the knitting construction. The fabric is tight when the stitch length is low.

The loop shape factor enabled us to evaluate the fabrics knitted at different course and wale densities and to compare their properties, which depend on the loop length, porosity, tightness, etc. of the knits. The loop shape factor is a comparative quantity, which is found as the ratio of course spacing and wale spacing, and depends on the knitting pattern and raw material of yarns. Experimental results obtained by Čiukas [29] showed that the loop shape factor depends on the course and wale spacings. Similar results were obtained in this study. As shown in ***Table 4***, the highest loop shape factor value of 1.88 was seen at the highest density value of the viscose fabric (0.27 cm loop length).

In general, the angle of spirality values decreases when the tightness factor values become higher in knitted fabrics. The tightness factor ranges from 11 (for slack fabrics) to 19 (for tight fabrics), where an average of 15 is preferable, which is generally the optimum [30]. According to ***Table 4***, all tightness factor values are between 12.82 and 16.70, in accordance with the literature [27, 30] The tightness factor and spirality were lower in the low density fabrics as compared to the high density fabrics for all fiber types.

As fabric density decreases, the unit fabric weight decreases and fabric spirality increases. According to ***Table 4***, as the yarn loop length increases, the number of courses and the fabric weight decrease. The results show that the weight of fabric is important for the spirality of all the fabrics. As the fabric density decreases, the fabric spirality value increases because the loops get looser. This situation exists for all fabric types. It can be seen from ***Figure 3*** that increasing the fabric weight results in decreasing spirality values for all the fabrics. According to the ANOVA results, the effect of the fabric weight on spirality was found to be significant ($p \leq 0.01$) at a 1% significance level. Similarly Degirmenci and Topalbekiroglu [8] also reported that fabric spirality decreased as the fabric weight increased in their study.

Fabric spirality values of the sample fabrics are given in ***Table 4***. The maximum spirality of the fabrics observed was found for 100% viscose and 95% viscose – 5% PES blended fabrics at a stitch length of 0.32 cm. ***Figure 4*** shows that fabric spirality increases radically with an increase in the knitting stitch length from 0.27 cm to 0.32 cm and vice-versa. The reason for the increase in spirality with an increasing loop length is probably due to the decreasing number of loops per unit area, which indicates the looseness of fabrics. As the loop length increases, the spirality angle increases. The reason for this behavior was explained by Degirmenci and Topalbekiroglu [8] by the possibility of loops turning freely in loose fabric structures. In a more tightly knitted fabric, the movement of a knitted loop is restricted, and thus spirality is reduced [28].

On the other hand, although spirality values of the 100% modal, 100% cotton and 100% organic cotton fabrics were found to be close to each other, the highest spirality value was measured for 100% modal fabrics at 0.27 cm and 0.32 cm loop lengths. The spirality values of 100% cotton and 100% organic cotton fabrics were measured at two fabric densities, and the results were similar.

The analysis showed that fiber type has significant influences on spirality values. There were statistically significant differences between the spirality values of the fabrics produced from 9 different fiber types (5% significance level). In their studies, Araujo [31] and Tao et al. [27] indicated that the raw material of yarns affects the fabric structure and spirality. Cotton fabrics with cotton fiber as raw material exhibit greater spirality behavior than that made from polyester fiber. The stabilisation of knitwear fabrics is difficult if the raw material is cotton, because it is non-thermoplastic in nature and cannot be heat-set to stabilise the knitted fabric dimensions [31]. Thermoplastic fibers cause less

Figure 5. *Example of a garment with faulty fabric spirality.*

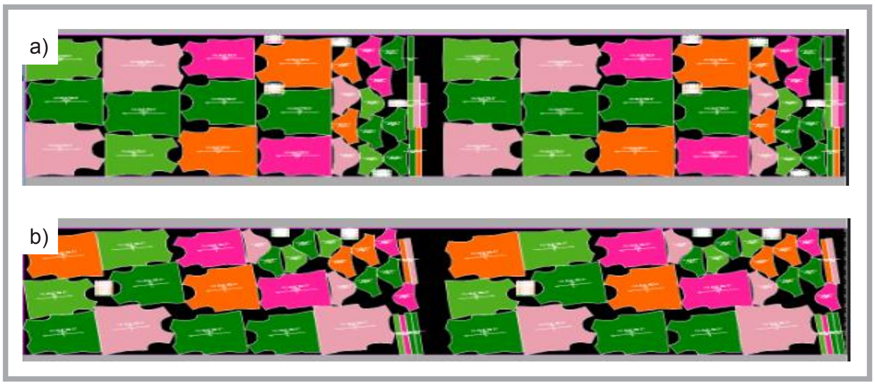


Figure 6. *a) Marker layout plan (12 sizes) – no spirality and b) marker layout plan (12 sizes) – 7% spirality rate.*

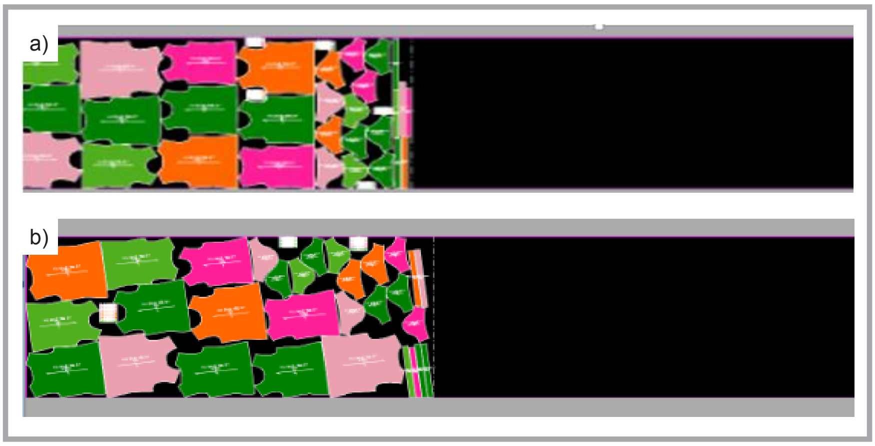


Figure 7. *a) Marker layout plan (6 sizes) – no spirality and b) marker layout plan (6 sizes) – 7% spirality rate.*

Table 5. *Unit fabric consumption results and CAD fabric utilisation ratio % results for all marker plans.*

Marker No.	Marker width, cm	Spirality of fabric %	Size breakdown, Assortment	Marker length, cm	Unit fabric consumption, cm	CAD fabric utilization ratio, %
1	153	0	12	648	58.49	77.4
2			6	327	57.27	79.05
3		5	12	727	60.66	74.66
4			6	338	59.17	76.99
5		7	12	733	61.54	73.56
6			6	342	59.93	75.54
7		10	12	754	62.84	71.92
8			6	349	60.97	74.03

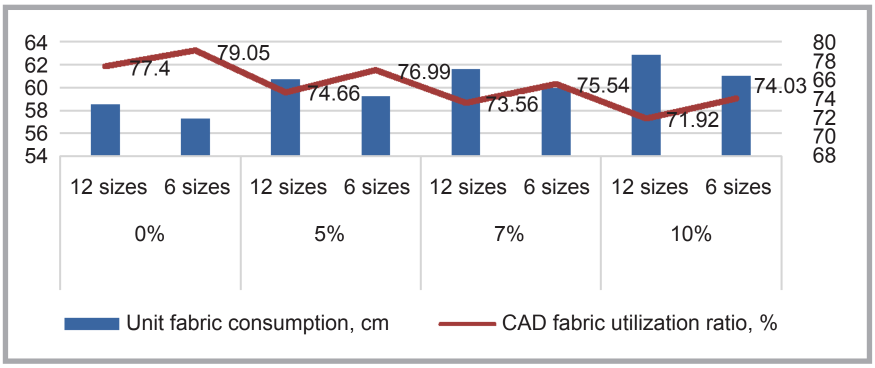


Figure 8. *CAD fabric utilisation ratio and unit fabric consumption for all marker plans.*

spirality [32]. Similar to their results, in this study the PES rate had an effect on spirality for viscose fabrics with the highest spirality value, according to ***Table 4***. Spirality did not occur in 70% Viscose-30% PES fabrics, but was seen in 95% Viscose-5% PES and 80% Viscose-20% PES fabrics.

It was found by some researchers that for fully relaxed fabrics, those with blended raw material (50/50 cotton/polyester blends and lyocell/cotton) have greater spirality than that of 100% cotton fabrics [27, 31, 33, 34]. In this study, as seen in ***Figure 4***, spirality values of the blend fabrics for all fabric types were lower than those of 100% pure fabrics.

Marker plan results

Spirality in a garment appears after washing, as a result of which one of the side seams comes to the front of the garment when the user wears it. Spirality percentage depends on the fabric torque and garment structure. ***Figure 5*** exhibits the displacement observed in side stitches of a garment manufactured from a fabric displaying spirality. While the hemline was measured to be 37 cm, the spirality value was found as 3.5 cm. Accordingly the spirality percentage of the t-shirt was calculated by 3.5/37*100 = 9.4%. The greater the dimensions of the apparel, the more apparent its spirality. Thus the spirality value of a t-shirt with a larger hemline would be greater in comparison with one with a narrower hemline. Therefore it could be suggested for reaching a more accurate conclusion that the spirality needs to be reported in cm or percentage per meter instead of using expressions of cm or percentage for the overall t-shirt product.

Especially fabric spirality could cause defects in apparel with striped designs, such as missing or un-matching lines on the final product.

When a marker plan is made for a knitted fabric already with spirality, a potential precaution could be paying utmost attention to the allocation of patterns over the fabric against defects that could arise. Otherwise the marker plan could deteriorate the consequences of spirality even further. In the fabric cutting process of the front and rear pieces of an apparel product, keeping the cutting direction the same for all garment parts could increase the spirality value of the product. On the other hand, using a counter cutting direction could decrease spirality to a certain extent by means of the counter-interaction of spirality directions.

In the present study, a certain t-shirt model was selected to determine the effect of fabric spirality on the fabric spread process. T-shirts were manufactured using 8 different fabric marker plans in 2 different assortments at 3 different spirality rates (5%, 7% and 10%). ***Table 4*** exhibits characteristics of the fabric marker plans prepared. ***Table 5*** also shows how fabric spirality affects fabric efficiency and unit fabric consumption according to the different fabric marker plans. ***Figures 6*** and ***7*** display the fabric marker layout of the fabric at a 7% spirality rate. In ***Figure 6***, the fabric marker layout is given in an assortment of 12 sizes, whereas ***Figure 7*** shows that for 6 different sizes for a plain fabric at a 7% spirality rate.

According to ***Table 5***, ***Figure 6*** and ***Figure 7***, as the spirality rate increases (0%, 5%, 7% and 10%), the CAD efficiency decreases with respect to the plan for fabric not exhibiting spirality.

In the fabric marker plan for the assortment prepared for 12 different sizes, marker efficiencies occured at rates of 77.4%, 74.66%, 73.56% & 71.92% (0%, 5%, 7% & 10%, respectively). In the fabric marker plan for the assortment prepared for 6 different sizes, marker efficiencies occured at rates of 79.05%,

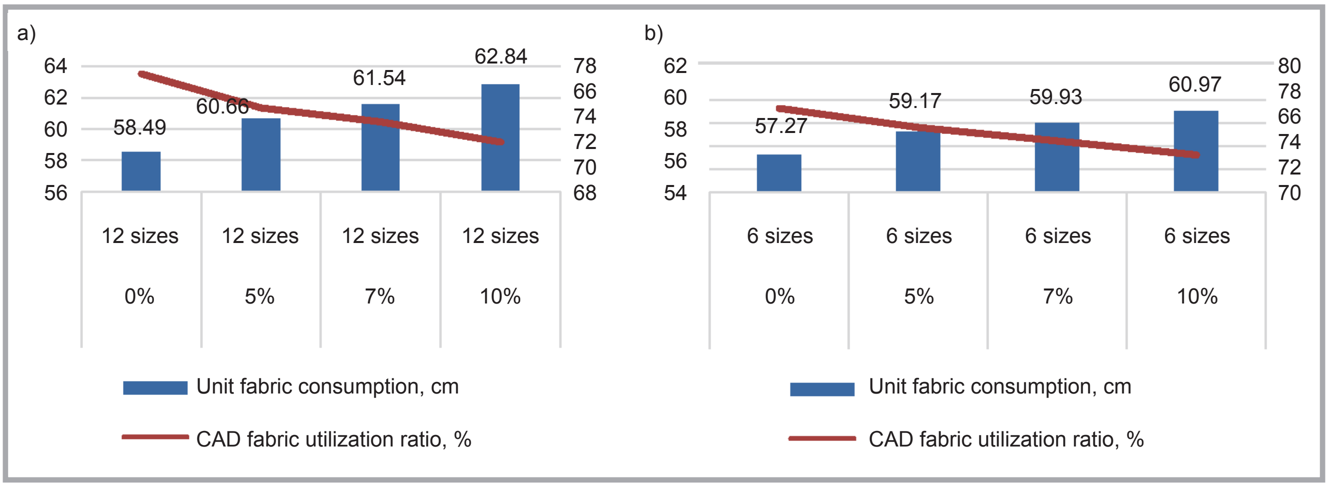


Figure 9. *a) CAD fabric utilisation ratio and unit fabric consumption for 12 sizes and b) CAD fabric utilisation ratio and unit fabric consumption for 6 sizes.*

76.99%, 75.54% & 74.03% (0%, 5%, 7% & 10%, respectively). According to ***Table 5***, fabric marker plans with a low assortment characteristic displayed more efficient results than the marker plans for the fabrics displaying a spirality problem.

Figures 8 and ***9*** summarise unit fabric consumption rates and CAD efficiencies of the marker plans for 12-size and 6-size assortments for fabrics with 0%, 5%, 7% and 10% spirality rates. Accordingly it was found that as the spirality rate increases, unit fabric consumption increases where CAD efficiency decreases.

According to ***Figure 9.b***, unit fabric consumption in the fabric marker plan with a low assortment was lower than that with a high assortment, shown in ***Figure 9.a***. For instance, the unit fabric consumptions measured for the marker with a 12-size assortment for the fabric exhibiting a 7% spirality rate and for the fabric with no spirality were 61.54 cm and 58.49 cm, respectively. The difference was 3.05 cm per t-shirt. When the total amount of the order was taken into consideration, the significance of the amount of fabric material wasted could be realised.

Conclusions

Unless necessary precautions are taken during raw fabric manufacturing and finishing processes against fabric spirality, apparel manufacturers could encounter problems. Apparel manufacturers take various precautions when they need to use fabrics with high spirality in the case of a rush order, one of which is using inclined fabric markers and planning the cutting process based on this layout. However, although these kinds of precautions are applied by manufacturers, they cannot avoid loss in terms of fabric consumption efficiency. The natural spirality existing in raw knitted fabrics can either be relieved by half in the dyeing and finishing processes [8] or, on the contrary, be worsened. When a wet fabric with high spirality is dried, its spirality level increases, and now requires even more difficult precautions. If a high spirality rate persists after dyeing and finishing processes, the fabric needs to undergo a finishing process once again by soaking. However, these additional operations are costly in terms of time and money.

Following conclusions could be drawn from the study:

- The highest spirality was seen with 100% viscose and 95% viscose-5% PES fabrics based on the results of fabric spirality analysis conducted for 18 different single jersey knitted fabrics manufactured from different raw materials in 2 different densities.
- The main reason for spirality was the residual torque of yarns. To minimise spirality, the loop length should also not be high, so that the yarns have less space to be untwisted. The higher the tightness factor of a fabric, the less the spirality will be. Thus the tightness factor of a fabric should be high if spirality is required to be under control.
- In all fabric types, the lower the fabric density, the lower unit fabric weight (mass per unit area-g/m^2) and the greater the fabric spirality was.
- In order to determine the effect of fabric spirality on the fabric spreading process, a t-shirt model was selected in 2 different assortments. It is determined that the CAD efficiency decreases by 2.4%, 3.68% & 5.25% for fabrics with 3 different spirality rates (5%, 7% & 10%, respectively) in comparison with the marker plan for the fabric not exhibiting spirality.

Spirality is a very complex phenomenon. The most appropriate solution would be keeping the spirality of knitted fabrics under control from the beginning, and to supply fabrics to the garment manufacturer with minimum spirality rather than conducting repair and correction processes.

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