Research Article

Study Effect of Twist Multipliers on Loop Length, Loop Shape, and Tightness Factors of Single Jersey and 1×1 Rib Knitted Fabrics

Dereje Berihun Sitotaw and Kathirrvellu Subban Subramanian

Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Bahir Dar, Ethiopia

Correspondence should be addressed to Dereje Berihun Sitotaw; dere96@yahoo.com

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The study focuses on effect of twist multiplier on single jersey and 1×1 rib knitted fabrics loop length, loop shape, and tightness factors properties. For the study 100% cotton fiber which is processed into 40Ne (English count) carded ring spun yarn is used. Three twist levels of 900 turns/m, 1050 turns/m, and 1200 turns/m with respective twist multipliers of 3.6, 4.2, and 4.8 are used. The single jersey produced from the three twist multipliers is named as Sj1 which is produced from 3.6, Sj2 from 4.2, and Sj3 from 4.8. Similarly, 1×1 rib is denoted as R1 which is produced from 3.6, R2 from 4.2, and R3 from 4.8. The test was performed as per ASTM D1776-Practice for Conditioning Textiles for Testing. The tests done for ten specimens and the results showed that loop length, loop shape, and tightness factors properties of single jersey and 1×1 rib knitted fabrics are significantly influenced by twist multipliers variation.

1. Introduction

The dimensional properties of knitted fabrics are vital in apparel application of knitted fabrics. These properties are dependent on loop length to high extent. The dimensional properties include loop length, wales and courses per unit length, stitch density, loop shape factor, take-up rate, and fabric width.

Loop lengths combine in the form of course lengths and it is these that influence fabric dimensions and other properties, including weight. Variations in course length between one garment and another can produce size variations, whilst course length variations within structures (particularly when using continuous filament yarns) can produce horizontal bareness and adversely affect the appearance of the fabric [1, 2].

Weft knitted structures, especially those used for hosiery, knitwear, and underwear, have unique properties of form-fitting and elastic recovery based on the ability of knitted loops to change shape when subjected to tension. Unfortunately, dimensional changes can also occur during

production, or washing and wearing, as problems of shrinkage and size variation can cause customer dissatisfaction and increased production costs [1].

The single jersey knitted fabric properties especially the dimensional and physical characteristics are mainly influenced by the constituent fibers, yarn properties, knitting machine variables, processing, and finishing treatments. Abdel Megeid et al. [3] and Munden [4] have extensively investigated the dimensional properties of wool and cotton knitted fabrics and predicted that the length of the yarn in the knitted loop plays a major role in determining the dimensions of knitted fabrics.

Yarn properties such as linear densities of yarns play a vital role in the dimension of weft knitted fabrics as they control the level of shrinkage in the yarn. Using coarser yarns will result in tighter knitted fabrics. This in turn influences the fabric loop length and loop shape factor properties. Loop length and tightness factors together with twist multipliers have an effect on air permeability property of single jersey and 1×1 rib knitted fabrics.

But researchers do not show the effect of twist multiplier on knitted fabrics dimensional properties such as on loop length, loop shape factor, and tightness factor. This paper mainly focuses on the analysis of twist multipliers effect on single jersey and 1×1 rib knitted fabrics dimensional properties.

2. Methodology

2.1. Methods. This research is designed to study the effect of yarn twist on the loop length, loop shape, and tightness factors properties of single jersey and 1×1 rib knitted fabrics by collecting different data and samples. Cotton is the dominant fiber for circular knitting machines in Ethiopia and its properties such as staple length, short fiber index, nep, trash %, and origin are identified for this study. The yarn process parameters, excluding yarn twist, are controlled, with constant value. The fabric properties which are planned to be studied in this paper are produced from variety of yarn twist with the same material, machine setting, and process parameters. The methods for this work are clearly listed below.

- (i) Produce yarn with different twist level and keep other yarn process parameters constant.
- (ii) Study yarn properties by carrying out proper testing.
- (iii) Produce knitted fabrics from the three different twist levels of yarn.
- (iv) Study the fabric loop length, loop shape, and tightness factor properties by carrying out proper testing.
- (v) Analyze the results obtained from testing using Microsoft Office excel and one way ANOVA from SPSS.

The data related to this research work is collected from MAA garment and textile factory and EiTEX laboratory (both are found in Ethiopia). Relevant data related to the effect of yarn twist on knitted fabric properties include fiber properties, spinning machine parameters, yarn property, knitting machine parameters, knitted fabric types, and test results are collected.

2.2. Materials and Equipment. The materials and equipment listed in Table 1 are used to measure the yarn and fabric properties for this research work.

2.2.1. Fiber Properties. Fiber properties mentioned were considered to produce the sample yarn and fabrics. These fiber properties were kept constant for the yarn production. Cotton fiber is used in this study for it is the dominant raw material in textile factories especially in Ethiopia. The test is done randomly by taking samples from five different bales and the average results are shown in Table 2.

2.2.2. Spinning Machine Parameters. The spinning machine parameters included in this work are related to ring spinning machine. For this purpose ring spinning machine was used.

TABLE 1: Equipments and materials used.

S/r number	Name of equipment	Tests	Located in
1	Atlas twist tester	Twist	MAA
2	Atlas count tester	Linear density of yarn	MAA
3	Uster tester-5	U%, CVM, thin, thick, Nep	MAA
4	Cutting dies	GSM, abrasion, pilling, bursting	MAA, EiTEX
5	Crimp tester	Loop length	EiTEX
6	Universal tensile tester for yarn	Yarn tensile strength and elongation	EiTEX

In MAA garment and textile factory (Ethiopia) there are ten ring frame machines of which five are for combed yarn and five for carded yarn. The machines are from RIETER Switzerland with the model G33⁺. The following lists of data are about ring spinning machine which are used to produce the yarns with it for the sample fabric production:

- (i) Machine type: RIETER G33+
- (ii) Material: carded, 100% cotton
- (iii) Twist: 900, 1050 and 1200
- (iv) Twist Factor: 3.6, 4.2 and 4.8
- (v) RPM: 16000
- (vi) Traveler: 25
- (vii) Spacer: 3.0 (White)
- (viii) Break Draft: 1.19 (69T)

2.2.3. Yarn Parameters. As the research was already done to study the effect of yarn twist on knitted fabric properties by testing the yarn and fabric sample using Zweigle Uster Tester standard and is used for analysis of the yarn properties related to twist effect. The yarn strength and elongation properties were measured by using Universal Strength Tester at 50 cm gauge length and 20 sec time to break. The data collected from MAA during yarn production with different twist levels are indicated in Table 3.

2.2.4. Knitting Machine Parameters. The two fabrics are produced with the machine parameters as indicated in Table 4. The fabrics for this study are produced on circular knitting machine.

2.2.5. Produced Fabric Parameters. The fabrics produced to be studied in this research are single jersey and 1×1 rib knitted fabrics produced from three different twist multipliers. The sample fabrics are produced with one roll of fabrics from each twist multipliers and 3 meters of fabrics are taken from each type to be tested. The fabrics are produced with the machine parameter as shown in Table 4.

TABLE 2: Fiber properties.

Type of fiber	Origin	Staple length	Properties Short fiber index	Nep	Trash%	Micronaire
Cotton (100%)	Indian	30.6	10.4	207.4	3.58	3.78

TABLE 3: Yarn properties.

Machine type	Machine number	Twist (1/m)	Ne	U%	CVM	Thin −50%	Thick +50%	Neps +200%	Strength (cN/Tex)	Elongation (%)
Ring frame	07	900		13.97	17.90	38.8	612.8	844	1.17	4.76
		1050	40	13.88	17.83	31.6	646.8	827.8	1.68	4.33
		1200		13.53	17.37	24.4	557.6	791.6	1.89	3.92

3. Experimental Study of Single Jersey and 1 × 1 Rib Knitted Fabrics Loop Length, Loop Shape, and Tightness Factor Properties

The knitted fabric properties to be studied in this research work are the dimensional properties. The study was done in the following order: loop length, loop shape, and tightness factor properties. The test was done as per American Society Standard for Testing and Materials (ASTM). With this standard many of the tests are done for ten specimens at the standard atmospheric condition at $21 \pm 1^\circ\text{C}$ and $65 \pm 2\%$ at EiTEX laboratory (ASTM D1776-98).

3.1. Determination of Loop Length, Loop Shape, and Tightness Factor Properties. Effect of yarn twist on knitted fabric loop length, loop shape, and tightness factor properties is studied. The study was carried out on dry relaxed state of single jersey and 1 × 1 rib knitted fabrics.

3.1.1. Knitted Fabric Loop Length. Loop length is the fundamental unit of weft knitted structure [1]. Stitch/loop length is the fundamental unit which controls all the properties of weft knitted fabrics. Mainly stitch length and knit structure affect all the dimensional, comfort, handle, and other properties [2, 5, 6]. The loop length was calculated using the crimp tester and measuring the unraveled yarn for ten courses for each twist level. The equipment for this test including crimp tester, scissor, and pick glass is used. Loop length is found by dividing the stretched yarn length by the number of loops in one course and expressed as follows:

$$\text{Loop length } (l) = \frac{\text{uncrimped yarn length in one course}}{\text{number of loops in one course } (n)} \quad [3].$$

The results of the test are shown in Table 5.

3.1.2. Loop Shape Factor. Loop shape determines the dimensions of the fabric, and this shape depends upon the yarn used and the treatment that the fabric has received [1, 7]. The loop shape factor of single jersey and 1 × 1 rib knitted fabrics is found from the mean results of wales and courses per unit length. It is determined by dividing the courses per centimeter by the wales per centimeter.

Loop shape factor (R) = CPCM/WPCM, where CPCM is courses per centimeter and WPCM is wales per centimeter. So, R values are calculated from Tables 6 and 7 and the loop shape results are shown in Table 8.

3.1.3. Tightness Factor. This property is required to measure the closeness and openness of knitted fabrics. In general it is a measure of level of fabric density [4, 8]. It is represented by K and expressed as follows:

$$K = \frac{\sqrt{\text{tex}}}{\text{loop length } (l)}, \text{ and Table 9 shows the results of tightness factor which is found from the average of loop length.}$$

4. Discussion

The study focuses on yarn twist multiplier effect on single jersey and rib 1 × 1 knitted fabrics loop length, loop shape, and tightness factor properties. Based on these factors, the analysis was done related to the loop length, loop shape, and tightness factors. For the analysis, one way ANOVA in SPSS and Excel are used. And we formulated the hypothesis for this study since statistical data cannot substitute engineering/science. It was formulated that

- (1) twist multipliers have an effect on knitted fabrics dimensional properties such as loop length, loop shape factor, and tightness factor because change in twist level brings change in yarn density, softness, smoothness, thickness, and evenness;
- (2) the dimensional properties of the two fabrics will be affected by twist multiplier. Twist multiplier is inversely proportional to loop length and loop shape factor and directly proportional to the tightness factor of single jersey and 1 × 1 rib knitted fabrics dimensional properties.

4.1. Loop Length. As shown in Table 5 loops length decreased as the twist multiplier increased. The average loop length for single jersey fabrics is 3.648 mm at 900 turns/m, 3.3 at 1050 turns/m, and 3.034 mm at 1200 turns/m. And rib 1 × 1 knitted fabrics have loop length 3.657 at 900 turns/m, 3.569 mm at 1050 turns/m, and 3.443 mm at 1200 turns/m.

TABLE 4: Knitting machine parameters for sample fabric production.

M/c type	Machine number	Speed (rpm)	Machine diameter (inch)	Number of needles	Gauge	Needle	Number of feeder	Number of cam tracks	Type of structure
MAYER & CIE	60	20	34	2976	28	Latch	108	4	Single jersey 1 × 1 rib
	99	20	30	1404	15	Latch	62	2	

TABLE 5: Loop length.

Fabric type	Sample number	Loop length (mm)										Average
		1	2	3	4	5	6	7	8	9	10	
Single jersey	Sj1	3.7	3.6	3.7	3.7	3.7	3.6	3.66	3.62	3.64	3.7	3.648
	Sj2	3.3	3.3	3.3	3.4	3.3	3.3	3.28	3.3	3.28	3.3	3.3
	Sj3	3	3.11	3	3.1	3	3	3.11	3.11	3	3	3.034
Rib 1 × 1	R1	3.7	3.66	3.7	3.6	3.7	3.7	3.63	3.66	3.69	3.7	3.657
	R2	3.6	3.59	3.6	3.5	3.6	3.6	3.57	3.6	3.59	3.6	3.569
	R3	3.4	3.41	3.5	3.5	3.4	3.5	3.46	3.46	3.45	3.5	3.443

TABLE 6: Wales per centimeter.

Fabric type	Sample number	Wales per centimeter (cm ⁻¹)										Average
		1	2	3	4	5	6	7	8	9	10	
Single jersey	Sj1	12	12	12	11	11	12	11	11.5	12	11	11.45
	Sj2	16	13	15	14	15	15	14	15.5	13	15	14.5
	Sj3	16	16.5	17	17	16	18	16.5	18	16	16	16.7
Rib 1 × 1	R1	17	17	17	17	17	17	17	17	17	17	17
	R2	17	21	19	19	18	20	19	21	20	18	19.2
	R3	23	22	22	23	24	23	23	24	23	24	23.1

TABLE 7: Courses per centimeter.

Fabric type	Sample number	Courses per centimeter (cm ⁻¹)										Average
		1	2	3	4	5	6	7	8	9	10	
Single jersey	Sj1	15	16	15	15	16	15	16	15	16	16	15.5
	Sj2	16	18	15	17	17	16	17	16	16	17	16.5
	Sj3	15	17	18	18	18	17	18	16	17	18	17.2
Rib 1 × 1	R1	10	11	11	11	10	11	10	10	11	11	10.6
	R2	12	11	12	11	12	12	12	12	11	12	11.7
	R3	13	12	12	12	13	12	13	13	13	12	12.5

TABLE 8: Loop shape factor for single jersey and rib 1 × 1.

Fabric type	Sample number	R
Single jersey	Sj1	1.35
	Sj2	1.14
	Sj3	1.03
Rib 1 × 1	R1	0.62
	R2	0.61
	R3	0.54

TABLE 9: Tightness factor.

Fabric type	Sample number	K (tex/mm)
Single jersey	Sj1	1.7
	Sj2	1.9
	Sj3	2.1
Rib 1 × 1	R1	1.7
	R2	1.8
	R3	2.01

The fabrics are made from 40Ne yarn with different twist level and loop length was varied.

This is due to the unwinding tension becoming more and the needle is not able to bend the yarn easily to intermesh with high twist level as compared to low twist yarn. So the needle fails to receive sufficient yarn and robbing back will be more than receiving from the feeder. Due to this robbing back, the loop length reduced with high twist of yarn. This in turn affects wales per centimeter and courses per centimeter. The mean differences between loop lengths in the single jersey and rib knitted fabrics produced from the three twist multipliers are significantly different as shown in multiple comparisons Table 10 with different effect level on the two fabrics.

Figure 1 shows the effect of twist multiplier on loop length of the two fabrics and as observed from Table 11, loop lengths of the two fabrics brought from the three twist multipliers are greatly independent of each other and have significantly different effect on loop length of the single jersey ($F = 558.920$, $P = 0.000$) and rib 1 × 1 ($F = 137.548$, $P = 0.000$) knitted fabrics.

TABLE 10: Multiple comparisons of loop lengths of knitted fabrics produced from three twist multipliers.

Dependent variable	(I) Knitted fabrics produced from different twist level	(J) Knitted fabrics from the three twist multipliers twist level	Mean difference (I - J)	Std. error	Sig.
Loop length of single jersey (mm)	900	1050	.34800*	.01842	.000
		1200	.61400*	.01842	.000
	1050	900	-.34800*	.01842	.000
		1200	.26600*	.01842	.000
	1200	900	-.61400*	.01842	.000
		1050	-.26600*	.01842	.000
loop length of rib (mm)	900	1050	.08800*	.01297	.000
		1200	.21400*	.01297	.000
	1050	900	-.08800*	.01297	.000
		1200	.12600*	.01297	.000
	1200	900	-.21400*	.01297	.000
		1050	-.12600*	.01297	.000

*shows that the effect is significant and not by laboratory errors.

TABLE 11: Analysis of variance for loop lengths of single jersey and rib 1 × 1 knitted fabrics.

		Sum of squares	Df	Mean square	F	Sig.
loop length of single jersey (mm)	Between groups	1.896	2	.948	558.920	.000
	Within groups	.046	27	.002		
	Total	1.942	29			
loop length of rib (mm)	Between groups	.231	2	.116	137.548	.000
	Within groups	.023	27	.001		
	Total	.254	29

FIGURE 1: Loop length of single jersey and 1 × 1 rib knitted fabrics.

FIGURE 2: Loop shape factor single jersey and rib 1 × 1 at 900, 1050, and 1200 turns/m.

4.2. Loop Shape Factor. As shown in Table 8 and Figure 2, loop shape factor varies as the twist multiplier varies. The loop shape reduces as the twist multiplier increases. Twist multiplier increases mean that the loop shape will become unclear and it affects the loop shape factor which is controlled during relaxation. So, knitted fabrics loop shape will be better in any type of relaxation state with lower twist multiplier.

4.3. Fabric Tightness Factor. Tightness factor of knitted fabric was determined by calculation from yarn linear density and loop length. The yarn linear density is constant, that is, 40Ne, but the loop length varies according to the level of TM which results in different tightness factor of knitted fabric. Tightness factor of single jerseys and 1 × 1 rib knitted fabrics attained different tightness between structures.

FIGURE 3: Effect of TM on tightness factor of knitted fabrics.

As shown in Table 9, single jersey produced from 900 turns/m (Sj1 TM = 3.6) has 1.73 tex/mm, single jersey produced from 1050 turns/m (Sj2 TM = 4.2) has 1.92 tex/mm, and single jersey produced from 1200 turns/m has 2.08 tex/mm tightness factor (k).

Similarly 1×1 rib fabric produced from 900 turns/m has 1.73 tex/mm, that of 1×1 rib produced from 1050 has 1.77 tex/mm, and rib 1×1 produced from 1200 turns/m has 1.84 tex/mm tightness factor. All the data are found from 40Ne of yarn count and average loop length.

As shown in Figure 3 effect of twist multiplier is different on these two structures. Single jersey is affected greatly compared to rib. The difference between tightness factors of knitted fabrics produced from low twist level and high twist level is 0.35 tex/mm in single jersey and 0.11 tex/mm in 1×1 rib. This shows that tightness factor is highly affected in single jersey compared to in rib by TM. Even though twist multiplier has influence on knitted fabrics the level of effect is different according to the type of structure and this because rib fabrics have balanced structure and loop length difference approaches one to the other. Single jersey knitted fabric was exposed greatly to robbing back of yarn.

5. Conclusion

Twist multipliers effects on loop length, loop shape, and tightness factors of single jersey and 1×1 rib knitted fabrics were studied in this paper and the effect is shown from the result and analysis in tables and figures. The study shows that the effect of twist multiplier on loop length, loop shape, and tightness factors properties of single jersey and 1×1 rib knitted fabrics is significant. The effect is seen on loop length where TM significantly influences the loop length of the two fabrics. This is because of the unwinding tension increases with an increase in TM, and the knitting needles fail to receive an optimum yarn length for the adjusted loop length before it reaches the needle running position (after loop length formation position or loop length pulling position). The other reason for loop length, tightness, and loop shape factors of the two fabrics' variation is the yarn elongation property. The yarn elongation property (Table 3) was reduced with an increase in twist multiplier. This elongation reduction in yarn

results in loop length reduction of the two fabrics. This in turn influences the loop shape and tightness factors of the single jersey and 1×1 rib knitted fabrics.

The loop length of both single jersey and 1×1 rib knitted fabrics reduced with an increase in TM and the mean differences in loop lengths of the single jersey and rib 1×1 knitted fabrics produced from the three different twist multipliers (TM) are significantly different.

The other two properties (loop shape and tightness factors) are also affected by twist multipliers for loop length is significantly influenced. Since the tightness factor property is inversely proportional to loop length, as twist multiplier increases the tightness factor increases. But loop shape factor reduces with an increase in twist multipliers due to high fabric shrinkage and the relaxation in dry state on high twist level is not effective.

This research work will help for knitted fabric manufacturers. If the knitting factory technologists are aware of effect of twist multipliers on knitted fabrics loop length, loop shape, and tightness factors, they can take measure for the appropriate material selection. Modeling of loop shape and tightness factors in relation to yarn twist multipliers and twist multiplier and relaxations effect on loop length, loop shape, and tightness factors are open for further research works.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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