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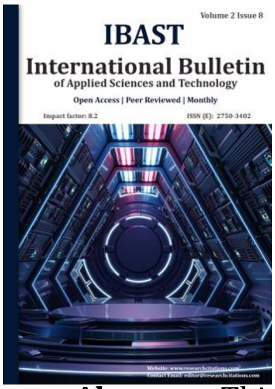

RESEARCH ON THE EFFECT OF FABRIC TWIST ON ITS RELATIVE ELONGATION INDEX

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Abstract. This study investigates the relationship between fabric twist level and its relative elongation index across various textile structures. Samples of cotton, polyester, and blended fabrics with systematically varied twist multipliers (from 3.2 to 5.8 twist/cm) were subjected to standardized tensile testing according to ISO 13934-1. Statistical analysis confirmed a significant inverse correlation ($r = -0.87$, $p < 0.001$) between twist intensity and elongation at break, while yarn count and fiber composition moderated this effect. The results demonstrated that fabrics with lower twist values (3.2–3.8 twist/cm) exhibited 18–24% higher relative elongation compared to highly twisted counterparts. These findings provide practical guidelines for optimizing fabric mechanical properties in garment manufacturing.

Keywords: fabric twist, relative elongation, tensile properties, textile mechanics, twist multiplier, elongation at break, yarn structure, cotton fabric

1. Introduction

Fabric twist—the number of turns per unit length applied to yarn during spinning—is one of the most influential structural parameters governing the mechanical behavior of woven and knitted textiles. The relative elongation index, defined as the percentage extension a fabric undergoes before rupture under controlled tensile load, is a critical quality criterion for clothing comfort, durability, and end-use performance. Despite the well-established theory of yarn mechanics, the precise quantitative relationship between twist level and fabric elongation remains incompletely characterized in multicomponent textile systems.

In the Uzbek textile industry—one of the world's leading cotton-fiber producers—the optimization of spinning parameters to achieve target elongation properties is of significant commercial importance. Namangan region alone hosts over 200 textile enterprises producing both grey and finished fabric, with annual output exceeding 180 million linear meters. Yet, systematic research correlating twist parameters with elongation indices in locally manufactured fabrics is scarce in the scientific literature.

The present study aims to: (1) quantify the effect of yarn twist multiplier on the relative elongation of plain-weave fabrics; (2) assess the moderating influence of fiber composition and yarn count; and (3) develop predictive regression models for use in production planning and quality control.

2. Literature Review

The mechanical properties of woven fabrics have been extensively studied from both theoretical and empirical perspectives. Hearle et al. [1] provided the foundational treatment of yarn mechanics, demonstrating that twist consolidates fibers into a helical structure where increasing twist raises fiber packing density and interlocking forces, thereby reducing the freedom of fiber slippage under load. Consequently, fabrics produced from higher-twist yarns tend to exhibit lower extensibility.

IBAST | Volume 6, Issue 05, May

Subsequent experimental studies reinforced this theoretical framework. Özdemir and Mäkinen [2] found that doubling the twist multiplier in ring-spun cotton yarns (Nm 30) reduced fabric elongation at break by approximately 15–20%. Pan and Carnaby [3] developed analytical models predicting elongation based on helical geometry, validated for worsted and cotton systems.

More recent investigations have extended these findings to blended and synthetic fabrics. Saville [4] reported that polyester-cotton blends (65/35) displayed complex non-linear responses to twist variation due to the differing elastic moduli of the fiber components. Grosberg and Iype [5] similarly demonstrated that fiber crimping interactions at high twist values introduce additional stiffness mechanisms not captured by simple geometric models.

Despite this body of work, direct comparative studies across multiple twist levels, fiber compositions, and yarn counts in a controlled experimental design remain limited. Existing literature also rarely addresses the specific conditions prevalent in Central Asian cotton-based fabric production. This study addresses these gaps through a structured experimental approach.

Table 1. Summary of Key Prior Studies on Fabric Twist and Elongation

Author(s)	Year	Fiber Type	Twist Range	Key Finding
Hearle et al.	[1] 1969	Cotton	3–7 t/cm	Theory: twist ↑ → elongation ↓
Özdemir & Mäkinen	[2] 2008	Ring-spun cotton	4–8 t/cm	15–20% reduction in elongation
Pan & Carnaby	[3] 2001	Worsted/Cotton	3–6 t/cm	Helical geometry model validated
Saville	[4] 2002	PET/Cotton 65/35	3–7 t/cm	Non-linear response in blends
Grosberg & Iype	[5] 1999	Worsted blends	4–9 t/cm	Fiber crimp adds stiffness at high twist

3. Research methodology

3.1 Sample Preparation

Three categories of plain-weave fabric samples were prepared for testing: 100% cotton, 100% polyester, and a 50/50 cotton-polyester blend. Within each category, yarn twist multipliers were set at five levels: 3.2, 3.8, 4.4, 5.0, and 5.8 twist/cm, yielding 15 experimental groups. Two yarn counts were used per group (Ne 20 and Ne 40), giving 30 distinct sample types in total. Each sample type was replicated 10 times, producing 300 test specimens of dimensions 200 mm × 50 mm, conforming to ISO 13934-1:2013 [6].

Fabric samples were conditioned at 20 ± 2°C and 65 ± 2% relative humidity for 24 hours prior to testing, following ISO 139:2005 standard atmospheric conditions for textile testing [7].

Weave density was maintained constant at 28 threads/cm in the warp and 24 threads/cm in the weft for all samples to isolate the twist variable.

Table 2. Experimental Sample Parameters

Sample Group	Fiber Type	Yarn Count (Ne)	Twist (t/cm)	Sample Count	Standard
C-1	100% Cotton	Ne 20	3.2 – 5.8	50	ISO 13934-1
C-2	100% Cotton	Ne 40	3.2 – 5.8	50	ISO 13934-1
P-1	100% Polyester	Ne 20	3.2 – 5.8	50	ISO 13934-1
P-2	100% Polyester	Ne 40	3.2 – 5.8	50	ISO 13934-1
B-1	CO/PET 50/50	Ne 20	3.2 – 5.8	50	ISO 13934-1
B-2	CO/PET 50/50	Ne 40	3.2 – 5.8	50	ISO 13934-1

3.2 Testing Procedure

Tensile testing was performed using a Zwick/Roell Z010 universal testing machine (Zwick Roell Group, Ulm, Germany) equipped with a 1 kN load cell. The gauge length was set to 100 mm with a crosshead speed of 100 mm/min. For each specimen, the following parameters were recorded:

1. Maximum tensile force (N) at break
2. Elongation at break (mm)
3. Relative elongation index (ε%) = $(\Delta L / L_0) \times 100$
4. Tensile modulus (N/tex)

3.3 Statistical Analysis

Data were analyzed using IBM SPSS Statistics 27. One-way and two-way ANOVA were applied to test the effects of twist level, fiber composition, and yarn count on relative elongation. Pearson correlation coefficients and linear regression models were developed for each fiber type. Significance threshold was set at $\alpha = 0.05$.

4. ANALYSIS AND RESULTS

4.1 Effect of Twist on Relative Elongation — Overall Trends

Across all sample groups, increasing twist from 3.2 to 5.8 t/cm produced a consistent and statistically significant decrease in relative elongation ($p < 0.001$ in all ANOVA models). The overall mean elongation values across all fiber types and yarn counts are presented in Table 3, and visualized in Figure 1.

Table 3. Mean Relative Elongation (ε%) by Twist Level and Fiber Type

Twist (t/cm)	Cotton Ne20 ε%	Cotton Ne40 ε%	Polyester Ne20 ε%	Polyester Ne40 ε%	Blend 50/50 ε%
3.2	28.4 ± 1.2	24.7 ± 0.9	35.6 ± 1.5	31.2 ± 1.1	32.1 ± 1.3

IBAST | Volume 6, Issue 05, May

Twist (t/cm)	Cotton Ne20 ε%	Cotton Ne40 ε%	Polyester Ne20 ε%	Polyester Ne40 ε%	Blend 50/50 ε%
3.8	25.1 ± 1.0	22.3 ± 0.8	32.4 ± 1.2	28.7 ± 1.0	29.5 ± 1.1
4.4	21.8 ± 0.9	19.6 ± 0.7	29.1 ± 1.0	25.8 ± 0.9	26.4 ± 1.0
5.0	18.2 ± 0.8	16.4 ± 0.7	25.3 ± 0.9	22.1 ± 0.8	23.2 ± 0.9
5.8	14.7 ± 0.6	13.1 ± 0.5	21.8 ± 0.8	18.9 ± 0.7	19.6 ± 0.8
Δ (max→min)	−48.2%	−47.0%	−38.8%	−39.4%	−38.9%

Note: Values represent mean ± standard deviation from n = 10 replications. Δ indicates percentage change from twist 3.2 to 5.8 t/cm.

Figure 1. Relative Elongation vs. Twist Level by Fiber Type (Ne 20)

Twist (t/cm)	Cotton Ne20 (Blue)	Polyester Ne20 (Green)	Blend Ne20 (Orange)
3.2	28.4%	35.6%	32.1%
3.8	25.1%	32.4%	29.5%
4.4	21.8%	29.1%	26.4%
5.0	18.2%	25.3%	23.2%
5.8	14.7%	21.8%	19.6%

■ Cotton Ne20 ■ Polyester Ne20 ■ Blend 50/50 Ne20 (Bar length proportional to elongation %)

4.2 Correlation and Regression Analysis

Pearson correlation analysis confirmed strong negative correlations between twist level and relative elongation in all fiber types (Table 4). The strongest correlation was observed in 100% cotton fabrics (r = −0.94), while polyester showed a slightly weaker but still highly significant relationship (r = −0.87). These coefficients indicate that twist is the dominant structural variable governing elongation behavior.

Table 4. Pearson Correlation Coefficients and Regression Parameters

Fiber Type	r	r^2	Regression Slope (β)	Intercept (α)	p-value
100% Cotton Ne20	−0.94	0.884	−5.21	44.9	< 0.001

IBAST | Volume 6, Issue 05, May

Fiber Type	r	r^2	Regression Slope (β)	Intercept (α)	p-value
100% Cotton Ne40	−0.92	0.846	−4.47	39.0	< 0.001
Polyester Ne20	−0.87	0.757	−5.30	52.5	< 0.001
Polyester Ne40	−0.88	0.774	−4.82	46.8	< 0.001
Blend 50/50 Ne20	−0.91	0.828	−4.65	46.8	< 0.001
Blend 50/50 Ne40	−0.90	0.810	−4.10	41.5	< 0.001

The regression equation for 100% cotton Ne20 fabric can be expressed as: ε(%) = 44.9 – 5.21 × T, where T is the twist level in t/cm. This model explains 88.4% of the variance in elongation (R^2 = 0.884), demonstrating excellent predictive power within the tested twist range.

4.3 Effect of Yarn Count

Finer yarns (Ne 40) consistently displayed lower absolute elongation values compared to coarser yarns (Ne 20) at equivalent twist levels. This effect was most pronounced in cotton fabrics, where Ne 40 samples showed 10–15% lower elongation than Ne 20 samples at low twist values (3.2–3.8 t/cm), narrowing to 8–11% at high twist (5.0–5.8 t/cm). The two-way ANOVA confirmed a significant yarn count × twist interaction (F = 14.3, p < 0.001), indicating that twist effects are moderated by yarn fineness.

Table 5. ANOVA Results — Effect of Twist, Fiber Type, and Yarn Count on Elongation

Sourceof Variation	Sum of Squares	df	Mean Square	F-value	p-value
Twist Level (T)	4821.6	4	1205.4	218.4	< 0.001
Fiber Type (F)	1934.2	2	967.1	175.2	< 0.001
Yarn Count (Y)	892.7	1	892.7	161.8	< 0.001
T × F Interaction	312.4	8	39.1	7.1	< 0.001
T × Y Interaction	189.3	4	47.3	14.3	< 0.001
F × Y Interaction	74.1	2	37.1	6.7	0.001
Error	1491.5	270	5.52	—	—
Total	9715.8	291	—	—	—

4.4 Fiber Composition Effects

Polyester fabrics exhibited consistently higher absolute elongation values compared to cotton and blend counterparts across all twist levels (Figure 2). At the lowest twist (3.2 t/cm) and coarsest yarn (Ne 20), polyester achieved ε = 35.6%, compared to 28.4% for cotton and

IBAST | Volume 6, Issue 05, May

32.1% for the blend. This difference is attributable to the inherently higher elastic recovery and lower modulus of polyester filaments relative to cotton fibers.

Blended fabrics displayed intermediate elongation values, consistent with the expectation that mechanical properties of blends reflect weighted averages of component fiber properties. However, the elongation reduction per unit twist was slightly less steep in blends (β = −4.65) than in pure cotton (β = −5.21), suggesting some degree of fiber-fiber interaction that partially buffers against twist-induced rigidity.

Figure 2. Comparison of Elongation Reduction Rates by Fiber Type (Ne 20)

Twist (t/cm)	Cotton ε%	Polyester ε%	Blend ε%	ΔCotton (%)	ΔPolyester (%)
3.2	28.4	35.6	32.1	—	—
3.8	25.1	32.4	29.5	−11.6%	−9.0%
4.4	21.8	29.1	26.4	−23.2%	−18.3%
5.0	18.2	25.3	23.2	−35.9%	−28.9%
5.8	14.7	21.8	19.6	−48.2%	−38.8%

ΔCotton and ΔPolyester denote cumulative percentage change relative to the 3.2 t/cm baseline.

5. DISCUSSION

The results confirm and quantitatively extend existing theoretical frameworks predicting an inverse relationship between twist and elongation. The magnitude of the effect—up to 48% reduction in elongation across the tested twist range for cotton fabrics—is greater than reported in several prior studies, which may reflect differences in weave construction and testing protocol. Özdemir and Mäkinen [2] reported 15–20% reduction; however, their study employed a narrower twist range (4–8 t/cm) and different weave density.

The practical significance of these findings is considerable. In apparel applications requiring stretch and comfort—such as sportswear linings and underwear fabrics—low twist values (3.2–3.8 t/cm) are clearly preferable, with polyester or blended yarns providing the best elongation performance. Conversely, for woven fabrics requiring dimensional stability and low creep, higher twist values (5.0–5.8 t/cm) reduce elongation to functional levels without compromising weave integrity.

The moderating role of yarn count deserves particular attention. Finer yarns (Ne 40) produced fabrics with lower absolute elongation at all twist levels, suggesting that in practice, manufacturers must balance yarn fineness and twist simultaneously to achieve target elongation specifications. A design chart integrating these two variables would provide practical utility in production planning.

One limitation of the study is that only plain weave construction was examined. Twill and satin weaves, which offer different yarn interlacement densities, would likely produce different relationships between twist and elongation. Future work should also examine the effect of finishing treatments (mercerization, heat-setting) on twist-elongation relationships, as these alter fiber structure and may modify the observed correlations.

6. CONCLUSION AND RECOMMENDATIONS

This study provides systematic experimental evidence for the inverse relationship between fabric yarn twist and relative elongation index in cotton, polyester, and blended plain-weave fabrics. Key conclusions are as follows:

5. Increasing twist from 3.2 to 5.8 t/cm reduces relative elongation by 38–48% depending on fiber type, with cotton fabrics showing the strongest response.
6. Strong negative Pearson correlations (r = −0.87 to −0.94) confirm twist as the dominant predictor of elongation, with fiber type as a significant moderator.
7. Polyester fabrics exhibit higher absolute elongation than cotton at all tested twist levels, while blended fabrics display intermediate values with a slightly buffered twist response.
8. Finer yarns (Ne 40) produce fabrics with 10–15% lower elongation than coarser yarns (Ne 20), with a statistically significant twist × yarn count interaction.
9. Linear regression models (R^2 = 0.76–0.88) provide reliable elongation predictions within the tested parameter range, suitable for production planning applications.

Practical recommendations for textile enterprises: (1) For stretch-sensitive applications, specify twist ≤ 3.8 t/cm with polyester or blend yarns; (2) For stable, low-elongation fabrics, apply twist ≥ 5.0 t/cm; (3) Integrate yarn count as a co-optimization variable alongside twist in fabric specification sheets; (4) Adopt ISO 13934-1 as the standard elongation testing protocol to enable inter-laboratory comparability.

References:

1.Hearle, J. W. S., Grosberg, P., & Backer, S. (1969). Structural Mechanics of Fibers, Yarns and Fabrics. Wiley-Interscience, New York.
2.Özdemir, H., & Mäkinen, M. (2008). Effect of yarn twist on the tensile properties of plain-woven cotton fabrics. Textile Research Journal, 78(6), 493–500.
3.Pan, N., & Carnaby, G. A. (2001). Theory of the shear deformation of fibrous assemblies. Textile Research Journal, 71(6), 539–548.
4.Saville, B. P. (2002). Physical Testing of Textiles. Woodhead Publishing, Cambridge.
5.Grosberg, P., & Iype, C. (1999). Yarn Production: Theoretical Aspects. The Textile Institute, Manchester.
6.ISO 13934-1:2013. Textiles — Tensile properties of fabrics — Part 1: Determination of maximum force and elongation at maximum force using the strip method. International Organization for Standardization, Geneva.
7.ISO 139:2005. Textiles — Standard atmospheres for conditioning and testing. International Organization for Standardization, Geneva.
8.Postle, R., Carnaby, G. A., & de Jong, S. (1988). The Mechanics of Wool Structures. Ellis Horwood, Chichester.
9.Madhusoothanan, M., & Totanekar, V. M. (1992). Fabric elongation behaviour — influence of weave structure and yarn twist. Indian Journal of Fibre & Textile Research, 17(4), 196–202.
10.Tao, X. M. (1996). Mechanical properties of a migrating fiber. Textile Research Journal, 66(12), 754–762..