Analysis of Correlation Between Stretch and Recovery Properties of Single Jersey Fabrics and Elongation Characteristics of Elastane Yarns

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I. Introduction

Stretch and recovery properties are critical for comfort and durability in knitted apparel. While single jersey fabrics inherently possess elasticity, the addition of elastane yarns (e.g., spandex, Lycra) enhances these properties [1]. However, the relationship between yarn-level elongation and fabric-level performance remains underexplored. This study addresses this gap by analyzing how elastane yarn types, counts, and processing stages affect fabric behavior.

II. LITERATURE REVIEW

A. Elastane Yarn Properties

Elastane fibers (spandex/Lycra) are polyurethane-based synthetic yarns that enhance fabric elasticity. Elastane yarns (Spandex and Lycra) are synthetic fibers known for exceptional elasticity, capable of stretching up to 800% of their original length. These polyurethane-based fibers exhibit low modulus (stretch easily under low force) with breaking tenacity of 0.5-1.0 g/denier. Lycra offers superior softness and stretchability, while Spandex provides better shape recovery. Both are thermally sensitive, with melting points around 350°F and prone to shrinkage in hot water, requiring careful processing [2], [3], [4], [5].

B. Fabric Performance and Elastane Integration

Elastane incorporation significantly impacts fabric dimensions, increasing stitch density while reducing loop length and overall shrinkage (up to 60% less than pure cotton). However, studies report conflicting effects on spirality, some show improvement with higher elastane content while others indicate increased spirality due to knitting tension. The yarn's contraction force alters fabric width and weight, creating tighter, denser structures [6], [7].

Elastane enhances key mechanical properties, with cotton/Lycra blends showing twice the elongation of pure cotton fabrics. Recovery performance depends on yarn count and plating - 40D yarns demonstrate 36% recovery versus 26% for 20D yarns. Full-plated constructions outperform half-plated ones in both stretch and recovery, making them preferable for performance garments [8].

C. Measurement Techniques

Advanced image processing techniques now allow researchers to study stretch fabrics without damaging them. Methods like edge detection and thermal imaging analyze fabric structure, stitch patterns, and heat properties. Porosity measurements using software like MATLAB help understand how fabrics behave under stress. These non-destructive tests provide accurate data on stretch and recovery, helping improve fabric design for comfort and performance [9], [10].

Existing studies have explored elastane's role in fabric performance, but a systematic quantification of how *in-fabric* elastane yarn stretch (across varying deniers, e.g., 20D–40D) translates to macroscopic fabric behavior particularly after each processing stages(greige, heat-set, finished), remains unresolved. This limitation hinders the tailored design of elastic textiles with predictable stretch and recovery properties. Our study bridges this gap by rigorously correlating yarn-level elongation with fabric-scale mechanics.

III. MATERIALS AND METHODS

A. Sample Preparation

The study employed single jersey fabrics knitted from 40s count cotton yarns plated with two elastane variants: Spandex-350C (available in 20D, 30D, and 40D deniers) and Lycra-162L (20D). All fabric samples maintained a consistent blend ratio of 95% cotton to 5% elastane by weight. Fabrics were evaluated at three processing stages: (1) greige state (untreated after knitting), (2) heat-set condition (processed at 200°C for 90 seconds using a stenter machine),

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and (3) finished state (dyed and softened at 160°C). This multi-stage approach enabled comprehensive analysis of processing effects on elastic properties.

B. *Testing Procedures*

Tensile testing was performed using an Instron universal testing machine equipped with a 500N load cell, following the LTD3 standard (7.5 lbs maximum load, 500 mm/min test speed). For each fabric variant, six specimens (10" × 3") were prepared - three each along the wale and course directions [11]. Simultaneous image acquisition employed a 4K high-resolution camera mounted on the Instron, with subsequent analysis using ImageJ software.

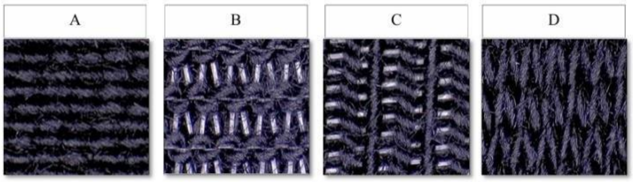

Figure 1: Visibility of elastane loops during stretching of the elastane plated cotton SJ fabric [Fig A - Backside widthwise stretching, Fig B - Backside lengthwise stretching, Fig C - Frontside widthwise stretching, Fig D - Frontside lengthwise stretching.]

This methodology enabled accurate quantification of loop length variations (Fig. 2) and real-time monitoring of yarn path deformation (Fig. 1). For stretch and recovery characterization, samples were first conditioned for 24 hours at 20°C and 65% relative humidity. Specimens were then subjected to tensile loading up to 33N, followed by a 5-minute relaxation period prior to final recovery measurements.

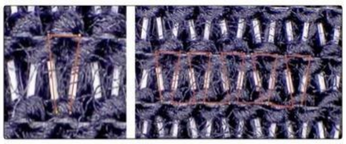

Figure 2: Assumed shape of the elastane loop and elastane yarn path on the backside of elastane-plated cotton single jersey fabric during lengthwise stretching.

C. *Data Analysis*

The initial measurements of loop extensions were obtained using ImageJ tracking, while fabric stretch values and recovered lengths were derived from Instron displacement data. Yarn elongation percentages, fabric stretch %, and recovery % were calculated using Equations (1), (2), and (3), respectively. Statistical analysis involved Pearson correlation coefficients (r) to assess yarn-to-fabric stretch relationships, supported by independent t-tests (significance threshold $p < 0.05$) comparing elastane types and yarn counts. This combined analytical approach enabled both parametric and non-parametric validation of the results. [12].

$$Yarn\ elongation(\%) = \frac{Elongated\ yarn\ length - Orginal\ yarn\ length}{Original\ length} \times 100 \quad (1)$$

$$fabric\ Stretch(\%) = \frac{Extended\ length - Orginal\ length}{Original\ length} \times 100 \quad (2)$$

$$Recovery(\%) = \frac{Extended\ length - Recovered\ length}{Extended\ length - Original\ length} \times 100 \quad (3)$$

IV. Results and Discussion

A. *Yarn vs Fabric Stretch*

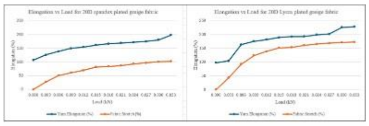

Figure 3: Yarn elongation & fabric stretch for spandex and Lycra plated fabrics.

The study examined how elastane yarns behave when knitted into fabrics, revealing important differences from their standalone performance. When embedded in cotton single jersey fabric, both Lycra-162L and spandex-350C yarns stretched significantly more than the overall fabric. Lycra yarns reached 228% elongation while the fabric stretched only 172%, and spandex yarns stretched 197% compared to 102% fabric stretch. This occurs because the surrounding cotton loops restrict the elastane's movement, preventing the yarns from achieving their full stretch potential.

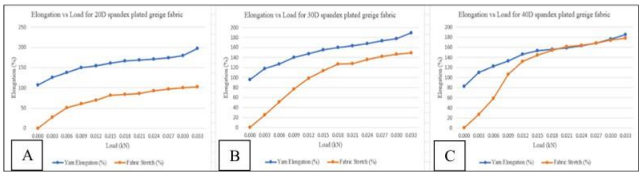

Figure 4: Elongation vs load graph [A- 20D spandex fabric, B- 30D spandex fabric, C- 40D spandex fabric]

The stretch difference between yarn and fabric depends on yarn thickness. Thin 20D yarns stretch much more freely in the fabric than the fabric itself. Medium 30D yarns show a moderate difference, while thick 40D yarns stretch only slightly more than the fabric. This happens because thin yarns slide easily between fabric loops, whereas thick yarns are stiffer and interact more with the fabric structure.

B. *Yarn Thickness Matters*

The study examined the stretch and recovery of fabrics made with 20D, 30D, and 40D spandex under increasing load. The 40D fabric stretched the most (178%) and had the best recovery (36.36%), showing that thicker spandex yarns provide greater elasticity and bounce back better. The 30D fabric showed moderate stretch (149%) and recovery (27.43%), while the 20D fabric stretched the least (102%) and had the lowest recovery (26.92%). These results indicate that higher-denier spandex (like 40D) enhances stretch and recovery, making it ideal for high-elasticity applications, whereas thinner spandex (like 20D) offers less stretch but better shape retention.

C. *Processing stages Makes a Difference*

Untreated greige fabrics exhibited maximum stretch but poor recovery due to unrestricted spandex movement. Heat-setting improved stability by partially binding yarns, reducing excessive elongation while maintaining flexibility. Finished fabrics showed optimal performance - slightly lower stretch than greige but significantly enhanced recovery, as thermal and chemical treatments strengthened yarn interactions.

V. CONCLUSION

The study examined how elastane yarns behave in knitted fabrics, showing their stretch is limited by interactions with cotton. Spandex fabrics showed bigger differences between yarn and fabric stretch than Lycra, especially with thinner (20D) yarns, with finer yarns (20D) showing more pronounced gaps than thicker ones (40D). Lycra provided better softness and stretch, while Spandex recovered better. Thicker (40D) yarns stretched more under tension and recovered better than thinner (20D) yarns. Fabric processing also affected performance: raw (greige) fabrics stretched most but recovered poorly, while heat-set and finished fabrics became more stable. The results highlight that both yarn choice and fabric structure impact stretch and recovery in garments.

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