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Influence of Tuck Stitch Variations on the Stretch Properties of Wool/PAN Single Weft-Knitted Fabrics

Vpliv različic razporeditve lovilnih petelj na raztezne lastnosti levo-desnih votkovnih pletiv iz mešanice volna/PAN

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Abstract
This study examines the stretch properties of nine variants of single-tuck weft-knitted fabrics made from 31 tex ×2 wool/PAN yarn and compares them with a plain fabric. The research emphasizes how variations in the arrangement and percentage of tuck loops within the stitch repeat affect the fabrics' stretch characteristics. Results show that the presence and percentage of tuck loops at the width repeat significantly influence stretch properties. The plain fabric displayed apparent anisotropy, with widthwise deformation roughly four times greater than lengthwise deformation. This behaviour was largely dominated by the elastic component, indicating strong immediate recovery and dimensional stability. In contrast, tuck stitch variants showed more balanced deformation between directions, reflecting the moderating influence of tuck loops on fabric anisotropy. Increasing the percentage of tuck loops improved lengthwise extensibility while decreasing widthwise recovery, thereby altering elastic and residual deformation behaviour. The analysis of deformation components revealed that tuck loops decrease the elastic deformation ratio and increase delayed and residual deformation, suggesting greater stress relaxation and a higher permanent set. These results highlight the sensitive interplay between the presence and combination of knit and tuck loops and their effects on loop configuration and fabric mechanics. The results thus confirm that the controlled use of tuck stitches provides a practical approach to optimizing fabric performance in terms of stretch, recovery and stability, thereby offering valuable insights for designing functional and high-performance knitted textiles.
Keywords: tuck stitches, stretch properties, wool, single weft-knit

Izvleček
V raziskavi so bile proučene raztezne lastnosti devetih različic levo-desnih lovilnih votkovnih pletiv in primerjane z lastnostmi enostavnega levo-desnega pletiva. Pletiva so bila izdelana iz preje z dolžinsko maso 31 tex × 2, iz mešanice volna/PAN. V raziskavi se je ugotavljal vpliv različic razporeditve in deleža lovilnih petelj (Tn) v sosledju na raztezne lastnosti pletiv. Enostavna pletena struktura kaže izrazito anizotropijo; deformacija v prečni smeri je približno štirikrat večja kot v vzdolžni smeri. Pri takšnem obnašanju pletiva pretežno prevladuje

elastična komponenta deformacije (E1), kar kaže na visoko takojšnjo elastično povratnost in dobro dimenzijsko stabilnost. Nasprotno pa strukture z različno razporejenimi lovilnimi petljami kažejo bolj uravnoteženo deformacijo v obeh smereh, kar pomeni zmeren vpliv lovilnih petelj na anizotropijo pletiva. Z naraščajočim deležem lovilnih petelj se povečuje razteznost v vzdolžni smeri, hkrati pa se zmanjšuje elastična povratnost v prečni smeri, kar vpliva na spremembo razmerja med elastično in trajno deformacijo. Analiza komponent deformacije je pokazala, da lovilne petlje zmanjšujejo delež elastične deformacije (E1/E) ter povečujejo delež zakasnele (E2/E) in trajne deformacije (E3/E), kar kaže na večjo sprostitev napetosti in večjo trajno deformacijo pletiv. Rezultati poudarjajo ključen vzajemni učinek zank in lovilnih petelj ter njihov vpliv na konfiguracijo zančne strukture in mehanske lastnosti pletiv. Rezultati raziskave potrjujejo, da je nadzorovana uporaba lovilnih petelj učinkovit pristop k optimizaciji uporabnih lastnosti pletiv, kot so razteznost, povratnost in dimenzijska stabilnost, ki so pomembne za razvoj funkcionalnih in visokozmogljivih pletenih tekstilij.
Ključne besede: lovilne petlje, raztezne lastnosti, volna/PAN, levo-desno votkovno pletivo

1 Introduction

Knitting is recognized as the second most versatile technique in textile manufacturing, surpassed only by weaving, where the choice and arrangement of stitches are among the most important factors in defining a fabric's characteristics [1]. Knitted fabrics are highly valued for their stretchability, flexibility and unique elastic properties, making them suitable for a wide range of uses, from clothing to technical textiles. These qualities primarily depend on the basic knitting elements, such as knit, miss (float) and tuck loops, and how they are arranged in single- and double-knit structures. Changes in these structural parts significantly affect fabric width, elasticity and overall performance, highlighting their important role in knitted fabric design [2, 3].

Tuck loops, together with knit and miss (float) loops, are essential structural features due to their distinctive loop shapes, which promote greater yarn movement, interloop spacing and porosity. Initial studies on composite uses revealed that tuck stitches in fabric significantly influence mechanical properties, including tensile, compressive and impact resistance. The unique geometry of tuck stitches allows for lateral stretch but can reduce overall dimensional stability [4]. Understanding the influence of knitted fabric structure on its properties can be based on geometrical modelling. This approach has shown that adding tuck stitches enhances the predictability of fabric structure and mechanical behaviour, highlighting their significance in creating complex knitted designs [5].

In both basic and derivative knitted structures, tuck loops generally increase fabric weight and thickness while enhancing dimensional stability [6, 7]. Tuck stitches significantly affect the structural and physical characteristics of knitted fabrics, resulting in higher weight, width and porosity than in single jersey fabrics. The number and placement of tuck loops and stitch length are critical factors that affect these properties and pilling resistance. Fabrics with larger, more numerous pores tend to resist pilling better, whereas single jersey fabrics usually have the lowest resistance. Dyeing and finishing processes also add to fabric weight but tend to decrease pilling resistance [8]. In circular knitting, the number and placement of tuck loops significantly affect bursting strength, with well-designed placements improving durability and performance. The results confirm that the precise placement of the tuck loop can significantly enhance the structural integrity of knitted fabrics [9]. Additionally, the contraction behaviour of weft-knit fabrics depends heavily on stitch type, stitch length and the placement of tuck and miss loops. Longer stitch lengths reduce widthwise contraction, while fabrics with miss loops show greater contraction than those with tuck loops. Single miss-knit fabrics display less contraction than plain structures at the same course length. The proper positioning of tuck and miss loops within a pattern is therefore crucial for controlling dimensional stability [10]. Variations in the number and placement of tuck loops, as well as their combination with knit and miss loops, significantly influence dimensional properties, mechanical behaviour under low stress and overall structural performance [11‒15]. Different stitch combinations, combining knit, tuck and miss loops, affect key physical properties such as areal density, thickness, air permeability, drape, stretch and recovery, and shrinkage, even under consistent knitting conditions. The addition of tuck and float knit structures significantly alters fabric drape [12]. Tuck loops have been shown to increase areal density, porosity, resistance to pilling, drape coefficient and fabric width, while maintaining dimensional stability, although they have little effect on colour fastness [16]. Beyond mechanical qualities, tuck structure design also influences aesthetic and tactile properties. When combined with other knit structures, such as eyelet, mesh or crochet, it facilitates diverse surface textures and visual effects, including concave-convex patterns and colour variations. This versatility enables designers to incorporate artistic expression, yarn choices and fashion trends into functional knitwear, blending performance with decorative appeal. Increasing tuck loops per wale reduces fabric width, affects shrinkage and spirality, and increases areal density, highlighting the importance of controlling tuck loops to optimise both performance and visual properties [17]. Moreover, tuck structures are important in the performance of weft-knitted strain sensors. Increasing the proportion of tuck loops lowers both initial and average resistance and improves the linearity of the piezoresistive response. This suggests that tuck loop configurations can be used to customize the electromechanical behaviour of knitted sensors, thereby enhancing their sensitivity for applications such as human motion detection [18]. The number of tuck and miss stitches significantly affects the properties of knitted fabric. Increasing their proportion reduces stretchability in both width and length, and decreases surface density. Tuck and miss stitches also reduce material usage, while miss stitches improve shape stability. Their most notable effect is on surface density, followed by volume density [19].

The placement and quantity of tuck loops significantly affect the thermo-physiological comfort of bi-layer knitted fabrics. Properly positioning tuck loops along the wale enhances air, heat and moisture transfer, while also decreasing fabric thickness and mass per unit area. This results in better thermal conductivity, air permeability, moisture absorption, drying speed and overall comfort. Fabrics with fewer tuck loops generally offer improved thermal comfort, as supported by objective tests and wearing trials [20]. Additionally, the ratio of knit to tuck loops significantly influences both physical and sensory comfort. Structure composition affects areal density, stitch density, thickness, resilience, softness, drape and wrinkle recovery. By carefully balancing knit and tuck loops, it is possible to achieve desired mechanical properties and increased comfort, emphasizing the importance of stitch design in creating multifunctional knitted fabrics [21]. Stress relaxation in knitted textiles is a time-dependent process where internal stresses diminish under sustained strain, which is important for applications such as compression garments and medical bandages that need consistent pressure. Including tuck loops in double jersey weft-knitted fabrics has been shown to reduce both initial and residual stress, thereby enhancing long-term performance stability.

This study systematically examines the effect of tuck stitch variations on the stretch behaviour of single weft-knitted fabrics made from a wool/PAN with 50% wool and 50% polyacrylonitrile fibres in the yarn. By implementing alternating tuck and plain courses and comparing them with traditional plain stitch, the research aims to clarify the relationship between stitch variants and fabric stretchability. This approach provides a better understanding of how tuck variants influence the structural changes that impact the mechanical and dimensional properties of knitted textiles. The findings are expected to provide a scientific foundation for optimizing knitting design parameters and offer practical guidance for creating high-performance knitted fabrics that balance durability, elasticity, comfort and aesthetic appeal.

2 Materials and methods

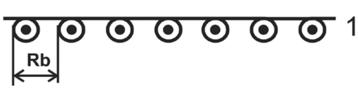
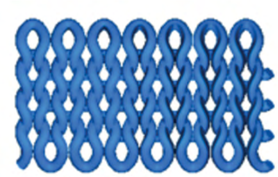
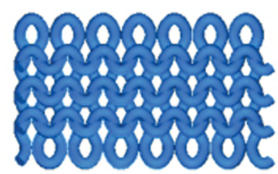
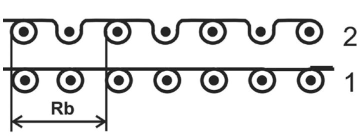
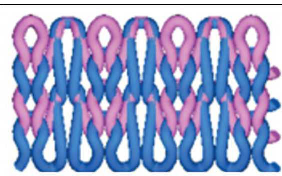
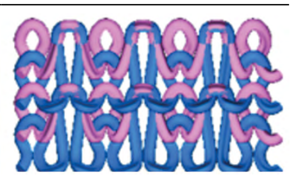
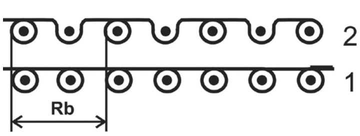
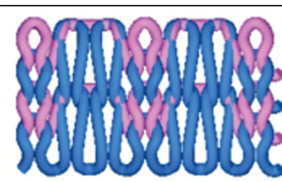
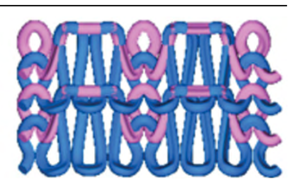
2.1 Materials

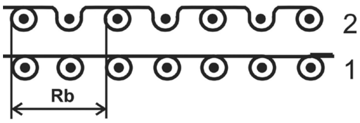
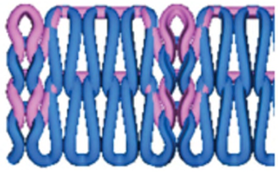
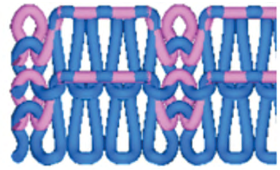
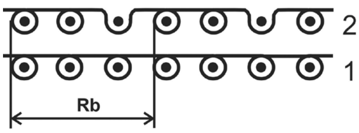
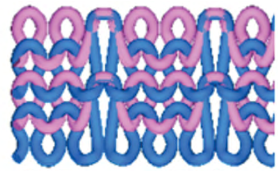
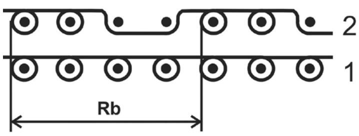
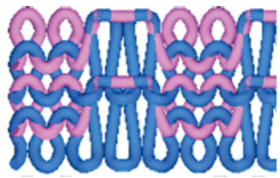
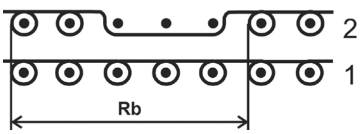
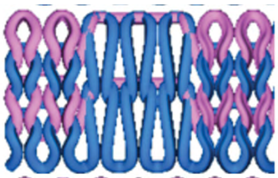
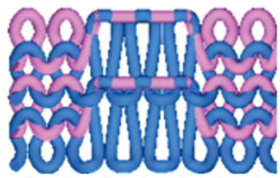
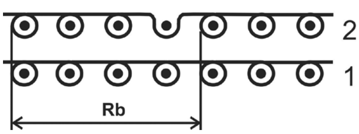
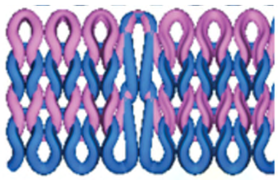
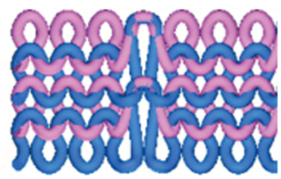
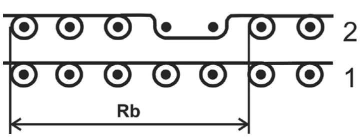
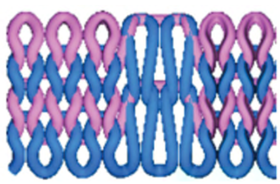
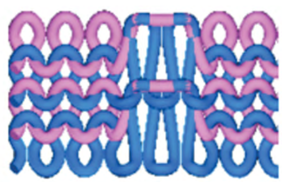
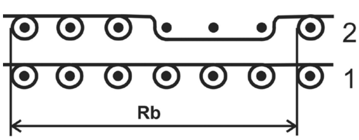
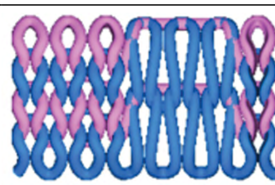
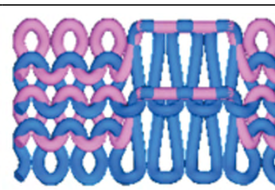
This study focuses on nine variants of single tuck fabrics (variants 2–10) and one plain fabric (variant 1) (Table 1). Each tuck stitch structure consists of one course of plain stiches (formed by the first yarn feeder), followed by one course of single tuck stitches (formed by the second yarn feeder). The knitted samples were produced on a 10-gauge flat V-bed knitting machine using a wool/PAN yarn containing 50% wool and 50% polyacrylonitrile (PAN) of 31 tex ×2. Throughout the knitting process, the stitch cam settings, yarn tension and fabric take-down were kept constant. Before knitting, the yarn was pre-treated with a 0.5% wax finish [22].

The tuck stitch index is set to one. The structure of the tuck stitch (Figure 1) consists of knit loops, which can appear as extended help loops (1) with tuck loops (2), and unextended knit loops (3). The head of the tuck loop is located on the reverse side of the fabric (the technical back). The unextended knit loops (3), which are located near the held loop with the tuck loop, usually have less height and a wider width, resembling a Ո-shape, compared to conventional knit loops, which are shown in the photo of the technical face side of the tuck stitch variant 2 (Figure 1a).

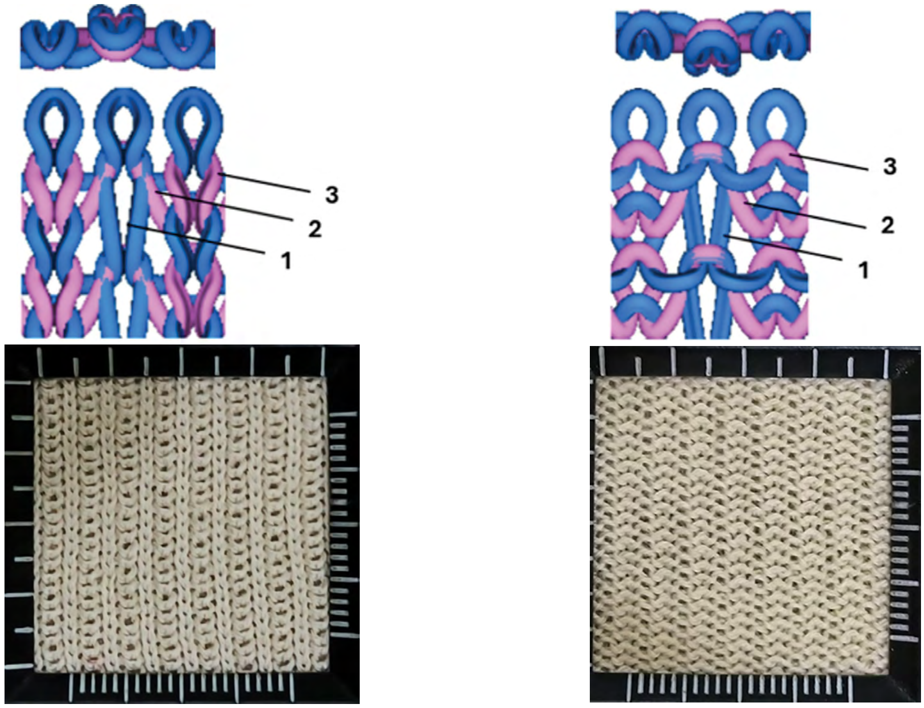
The studied variants of the single tuck stitches consist of a tuck loop produced over one, two or three adjacent needles, while various combinations of knit (m) and tuck (n) loops at the width repeat R_b define the tuck stitch variants. The number of knit (m) and tuck (n) loops in the tuck stitch structures across the fabric width can likewise be one, two or three. Different combinations of knit (m) and tuck (n) loops produced variations of the tuck stitches 2–10.

Table 1: Graphical notations and visual illustrations of the single-knitted fabrics

Variants of fabric	T_n a) (%)	Graphical notation of the repeat at height, R_h	Illustration of the view of the structure from the side	
			Technical face	Technical back
1	0			
2	50			
3	66.6			

4	75			
5	33.3			
6	50			
7	60			
8	25			
9	40			
10	50			

[a] percentage of tuck loops



a) b)

Figure 1: Illustration and photos of the technical face of tuck stitch knitted fabric variant 2:
a) technical face, b) technical back (1 - held loop, 2 - tuck loop, 3 - knit loop)

The percentage of tuck loops within the tuck stitch repeat across the fabric width (T_n) was calculated using the following equation:

$$T_n = \frac{n}{m + n} \times 100[\%] \quad (1),$$

where m represents the number of knit loops within the tuck stitch repeat across the width R_b, and n represents the number of tuck loops within the tuck stitch repeat across the width R_b.

2.2 Methods

Relaxation conditions

Following the knitting process, the fabrics were conditioned under standard atmospheric conditions for testing, in accordance with ISO 139:2005 [23]. They were then washed in a fully automatic domestic washing machine using the wool cycle, as prescribed by ISO 6330:2021 [24].

Average stitch length

The stitch length of the knitted fabric was measured separately for plain and tuck stitches, and expressed as the average yarn length per stitch, in accordance with the EN 14970:2006 [25] and GOST 8846-87 [26] standards. Measurements were conducted over a section containing 50 wales. Each reported value represents the mean of twenty individual measurements for both the plain stitch length () and the tuck stitch length (). The overall average stitch length () was then calculated from the individual stitch lengths using the following equation:

$$l_a = \frac{l_p + l_t}{2} \text{ [mm]} \quad (2)$$

Stretch characteristics

The stretch characteristics of the single-tuck and plain stitches were measured by determining full, elastic, delayed and residual deformations, together with their contributors, according to GOST 8847-85 [27].

For determining the stretch characteristic, a "rack" relaxometer was used to conduct a "loading–unloading-rest" cycle [13, 14]. During testing, the samples were loaded with 6 N for 60 minutes. The samples were then unloaded and given a 120-minute rest period (Figure 2). Fabric specimens, each 50 mm wide and 200 mm long, were first clamped at a gauge length of 100 mm (L_0). The displayed results represent the averages of five samples for each direction (in length and width).

The lengthwise and widthwise stretch characteristics were calculated using the following formula:

a) full deformation (E):

$$E = \frac{L_1 - L_0}{L_0} \times 100[\%] \quad (3),$$

where L_0 represents the initial length of the specimen, mm (L_0 = 100 mm) and L_1 represents the length of the specimen after 60 minutes of loading in mm.

b) elastic deformation (E_1):

$$E_1 = \frac{L_1 - L_2}{L_0} \times 100[\%] \quad (4),$$

where L_2 represents the length of the specimen just after unloading in mm.

c) delayed deformation (E_2):

$$E_2 = \frac{L_2 - L_3}{L_0} \times 100[\%] \quad (5),$$

where L_3 represents the length of the specimen after resting in mm.

d) residual deformation (E_3):

$$E_3 = \frac{L_3 - L_0}{L_0} \times 100[\%] \quad (6)$$

Based on the full, elastic, delayed and residual deformations, the contributions of each component to the full deformation, such as E_1/E, E_2/E, and E_3/E, was calculated.

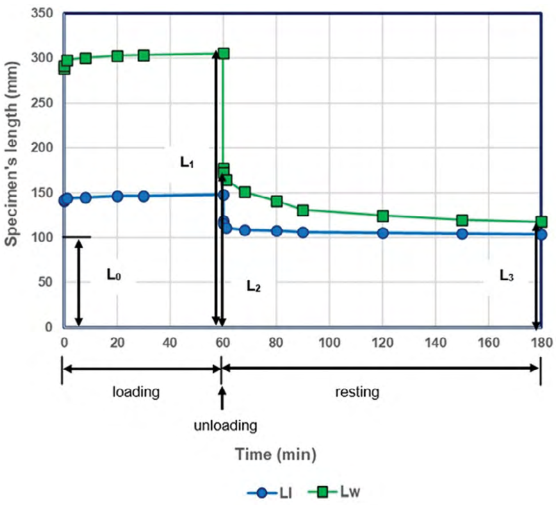


Figure 2: Specimen`s length changes of the plain (variant 1) within the cycle of "loading-unloading-resting" in both directions

Statistical analysis

The data were analysed statistically using the Student's t-test for independent samples, following the formula below:

$$t = \frac{|\overline{x_1} - \overline{x_2}|}{\sqrt{\frac{\sigma_1^2 \cdot (n_1 - 1) + \sigma_2^2 \cdot (n_2 - 1)}{n_1 + n_2 - 2} \cdot \frac{n_1 + n_2}{n_1 \cdot n_2}}} \quad (7),$$

where $\overline{x}_1$ and $\overline{x}_2$ represent the samples' mean values of the determined characteristic, σ_1 and σ_2 represent the sample's standard deviation of the determined characteristic and n_1 and n_2 represent their corresponding sample sizes ($n_1 = n_2 = 5$).

4 Results and discussion

Stitch length

The different tuck stitch variants directly influence stitch length by affecting the number of knit and tuck loops within each stitch repeat (Figure 3). Although the knitting machine's settings remained constant during production, the plain stitch length (l_p) of the fabric variants changed by up to around 5%, except for variant 8, which deviated by 10.7%. The tuck stitch length (l_t) depends on both the number and arrangement of the knit and tuck loops. When the number of knit loops (m) increases from 1 to 3 with a constant number of tuck loops (n), the tuck stitch length (l_t) increases proportionally. The relationship between the average stitch length (l_a) is linear (Figure 3), with an increase of 69.3%, when the percentage of tuck loops (T_n) reaches 75%.

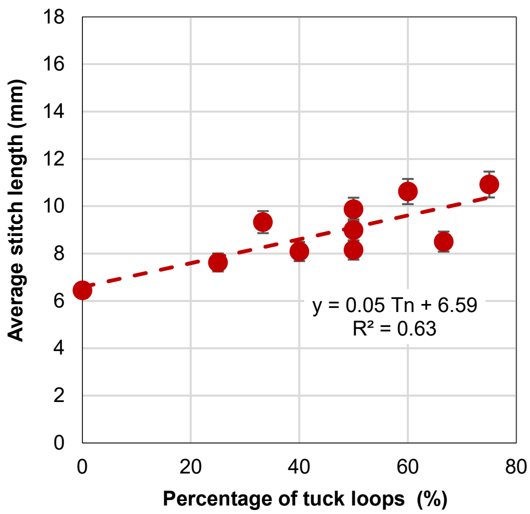


Figure 3: Dependence of average stitch length (l_a) and the percentage of tuck loops (T_n) in the tuck stitch repeat

Stretch characteristics

The results of the lengthwise and widthwise stretch characteristics of the single-tuck knitted fabrics are presented in Tables 2 and 3, respectively.

A specimen's length variations of the plain (variant 1) throughout the "loading-unloading-resting" cycle in both directions are illustrated in Figure 2.

An analysis of the stretch characteristics of the plain fabric reveals that the material exhibits significant anisotropic behaviour, with total deformation in the widthwise direction (205.8%) exceeding that in the lengthwise direction (48.0%) by a factor of four (Tables 2 and 3). In tuck stitch variants (variants 2-10), this trend is less noticeable and varies depending on the specific tuck stitch variant. In both plain fabric orientations, the elastic component (E_1) predominates, accounting for approximately 60–62% of the overall deformation, indicating the fabric's substantial capacity to revert to its original dimensions upon load removal. The delayed (E_2) component accounts for 29–32% of the total deformation, indicative of viscoelastic behaviour associated with gradual yarn relaxation. Meanwhile, the residual (E_3) component remains low at 7.5–8.6%, which confirms the fabric's good dimensional stability.

Table 2: Lengthwise stretch characteristics of knitted fabrics after washing

Fabric variants	T_n [a] (%)	m-n [b]	l_a [c] (mm)	Deformations (%) and their contributors						
				E [d]	E_1 [e]	E_2 [f]	E_3 [g]	E_1/E [h]	E_2/E [i]	E_3/E [j]
1	0	1-0	6.45 ± 0.16	48.0 ± 4.5	29.0 ± 3.9	15.4 ± 0.9	3.6 ± 1.1	0.60	0.32	0.07
2	50	1-1	8.16 ± 0.39	88.8 ± 4.1	47.6 ± 4.0	27.8 ± 1.5	13.4 ± 1.1	0.54	0.31	0.15
3	66.6	1-2	8.51 ± 0.31	80.8 ± 8.7	41.6 ± 6.3	22.0 ± 1.6	17.2 ± 3.6	0.51	0.28	0.21
4	75	1-3	10.92 ± 0.32	62.2 ± 2.9	34.0 ± 2.6	18.8 ± 1.9	9.4 ± 1.8	0.55	0.30	0.15
5	33.3	2-1	9.33 ± 0.34	69.0 ± 10.6	40.2 ± 9.1	18.8 ± 2.6	10.0 ± 3.2	0.58	0.28	0.14
6	50	2-2	9.87 ± 0.48	71.4 ± 7.8	43.2 ± 6.9	21.6 ± 1.5	6.6 ± 0.6	0.60	0.30	0.09
7	60	2-3	10.62 ± 0.06	77.8 ± 10.5	38.0 ± 5.8	25.0 ± 3.5	14.8 ± 4.1	0.49	0.32	0.19
8	25	3-1	7.63 ± 0.03	59.2 ± 6.4	26.4 ± 8.3	23.4 ± 3.3	9.4 ± 1.1	0.44	0.40	0.16
9	40	3-2	8.09 ± 0.04	69.4 ± 4.7	41.6 ± 4.3	20.2 ± 0.8	7.6 ± 2.0	0.60	0.29	0.11
10	50	3-3	9.00 ± 0.23	62.6 ± 5.4	34.8 ± 4.8	19.4 ± 2.7	8.4 ± 1.5	0.55	0.31	0.14

[a] percentage of tuck loops, [b] the number of knit and tuck loops, [c] average stitch length, [d] full deformation, [e] elastic deformation, [f] delayed deformation, [g] residual deformation, [h] contributors of elastic deformation in full, [i] contributors of delayed deformation in full, [j] contributors of residual deformation in full

Table 3: Widthwise stretch characteristics of knitted fabrics after washing

Fabric variants	T_n [a)] (%)	m-n [b)]	l_a [c)] (mm)	Deformations (%) and their contributors						
				E [d)]	E_1 [e)]	E_2 [f)]	E_3 [g)]	E_1/E [h)]	E_2/E [i)]	E_3/E [j)]
1	0	1-0	6.45 ± 0.16	205.8 ± 16.9	128.4 ± 12.3	59.6 ± 5.6	17.8 ± 2.3	0.62	0.29	0.09
2	50	1-1	8.16 ± 0.39	84.6 ± 3.4	43.0 ± 2.5	27.2 ± 1.8	14.4 ± 2.3	0.51	0.32	0.17
3	66.6	1-2	8.51 ± 0.31	99.0 ± 3.3	45.6 ± 3.5	27.4 ± 1.5	26.0 ± 1.2	0.46	0.28	0.26
4	75	1-3	10.92 ± 0.32	103.4 ± 6.9	53.6 ± 6.4	30.8 ± 2.1	19.0 ± 2.1	0.52	0.30	0.18
5	33.3	2-1	9.33 ± 0.34	142.2 ± 8.1	70.4 ± 6.8	50.0 ± 2.8	21.8 ± 1.1	0.49	0.35	0.15
6	50	2-2	9.87 ± 0.48	115.2 ± 10.4	67.6 ± 6.7	32.0 ± 4.5	15.6 ± 0.6	0.59	0.28	0.14
7	60	2-3	10.62 ± 0.06	112.6 ± 15.3	47.0 ± 7.5	29.8 ± 3.1	35.8 ± 5.0	0.42	0.27	0.32
8	25	3-1	7.63 ± 0.03	170.6 ± 9.2	92.8 ± 6.1	51.4 ± 3.2	26.4 ± 2.9	0.54	0.30	0.15
9	40	3-2	8.09 ± 0.04	130.0 ± 8.3	77.4 ± 5.1	34.0 ± 5.2	18.6 ± 1.7	0.60	0.26	0.14
10	50	3-3	9.00 ± 0.23	138.8 ± 8.0	79.2 ± 5.1	36.2 ± 4.4	23.4 ± 1.1	0.57	0.26	0.17

[a)] percentage of tuck loops, [b)] the number of knit and tuck loops, [c)] average stitch length, [d)] full deformation, [e)] elastic deformation, [f)] delayed deformation, [g)] residual deformation, [h)] contributors of elastic deformation in full, [i)] contributors of delayed deformation in full, [j)] contributors of residual deformation in full

The stretch properties of knitted fabrics are predominantly determined by the type of loop structure and the physical characteristics of the yarn [28]. Under tensile stress, deformation in plain and tuck stitches occurs through the redistribution of yarn within the constituent parts of the knit structure, including the knit and tuck loops and their components: the head, sinker loop and legs. The extent and configuration of tuck loops significantly influence a fabric's geometry and, thus, its mechanical response and elasticity.

The obtained results indicate that the presence and percentage of tuck loops significantly affect the stretch properties of the fabrics in both lengthwise and widthwise directions. Specifically, the inclusion of tuck loops led to increased elongation in the lengthwise direction (Figure 4 a–c) and a corresponding reduction in widthwise stretch compared to plain knitted structures (Figure 4 d–g), as was also noted in the study [16]. The decrease in widthwise stretching as the percentage of the tuck loop in width repeat increases follows the same trend as the increase in the miss-stitch rate in single-knit fabrics [13].

The full deformation lengthwise (E_l) of tuck stitch fabrics is generally equal to or only 1.2–2.2 times higher than the widthwise full deformation (E_w) (Tables 2 and 3). Comparing the lengthwise stretch properties of tuck stitch variants (2–10) with the plain stitch fabric (variant 1) highlights several key points (Table 2 and Figure 4 a–c). Tuck stitch fabrics show higher full (E), elastic (E_1), delayed (E_2) and residual (E_3) deformations in the lengthwise direction compared to plain fabrics. The full lengthwise deformation (E) of tuck stitch variants ranges from 59.2% to 88.8%, compared to 48.0% for the plain stitch variant, indicating that tuck loops contribute to structural changes that enhance fabric extensibility. Elastic deformation (E_1) varies from 26.4% to 47.6% in tuck stitch fabrics, slightly exceeding the plain value of 29.0%, suggesting better immediate recovery. Delayed deformation (E_2) ranges from 19.4% to 27.8% in tuck stitches, higher than the 15.4% for the plain stitch variant, reflecting increased viscoelastic behaviour. Residual deformation (E_3) ranges from 7.6% to 17.2%, which is significantly above the 3.6% for the plain stitch variant, indicating a greater permanent set after loading.

Variants with an equal number of tuck loops showed similar levels of lengthwise delayed deformation (E_2). Specifically, variants with 50.0% tuck loops (variants 2, 6, and 10) showed that delayed deformation contributed $E_2/E = 0.30–0.31$ to the total deformation. The same trend has been observed for single weft-knitted fabrics with the same percentage of miss loops [13].

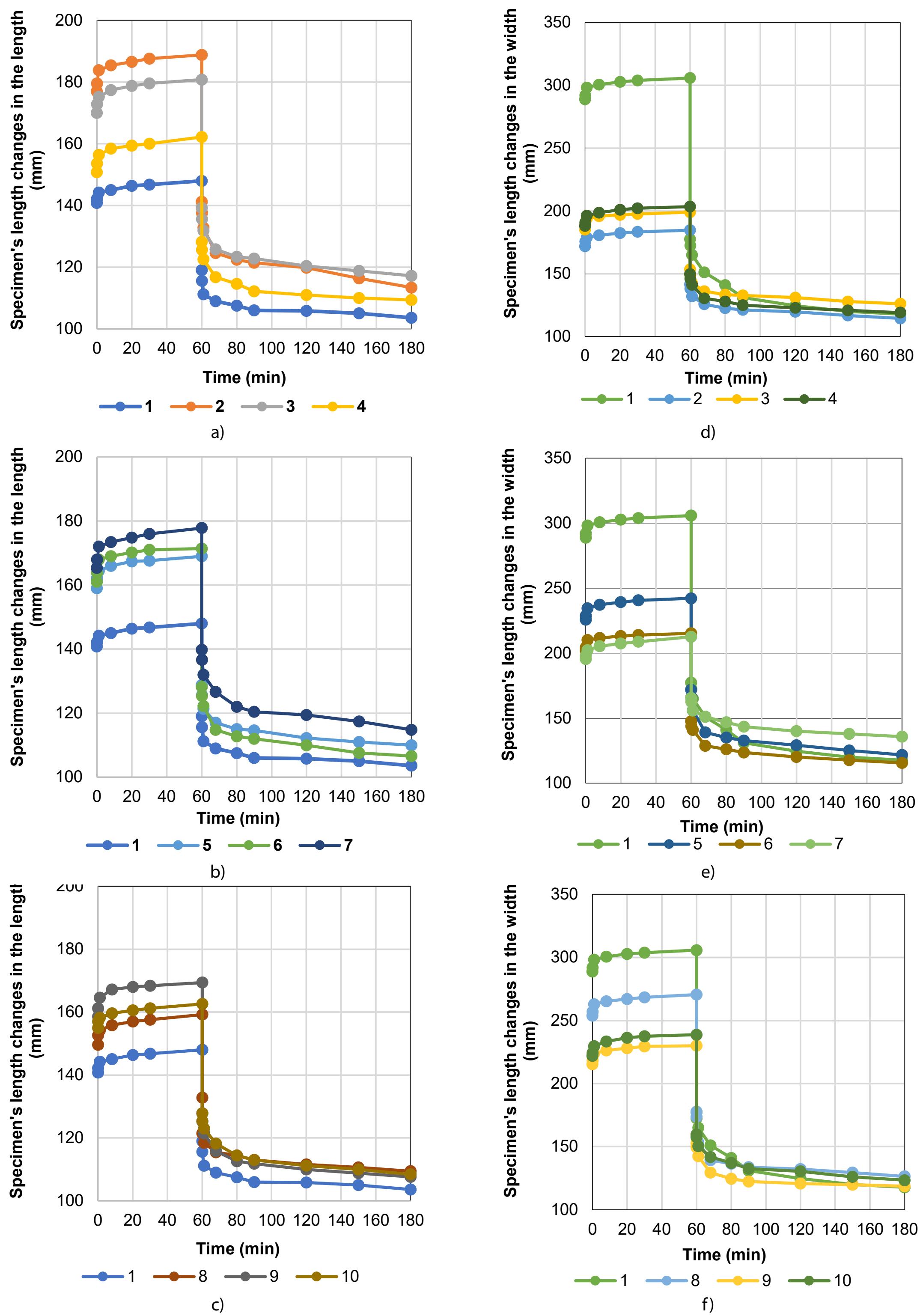


Figure 4: Specimen's length changes within the cycle of "loading-unloading-resting" for knitted fabrics in the length direction for tuck loops (n = 1, 2, 3): a) for variants 1 and 2-4 (m = 1), b) for variants 1 and 5–7 (m = 2), c) for variants 1 and 8–10 (m = 3); in the width direction for tuck loops (n = 1, 2, 3): e) for variants 1 and 2-4 (m = 1), f) for variants 1 and 5–7 (m = 2), g) for variants 1 and 8–10 (m = 3)

Conversely, the widthwise stretch properties of tuck stitch fabrics (2–10) display opposite trends. These fabrics exhibit lower full (E), elastic (E_1) and delayed (E_2) deformations in the widthwise direction than the plain stitch variant, except for the residual deformation (E_3). The full widthwise deformation (E_w) ranges from 84.6% to 170.6% across tuck stitch variations, indicating decreased overall fabric extensibility, compared to 205.8% for the plain. Elastic deformation (E_1) varies from 43.0% to 92.8% in tuck stitch fabrics, showing less immediate recovery, whereas the plain exhibits a higher value of 128.4%. Delayed deformation (E_2) ranges from 27.2% to 51.4% in tuck stitches, which is lower than the 59.6% observed in the plain stitch variant, implying lower viscoelasticity. Residual deformation (E_3) in tuck stitch fabrics ranged from 14.4% to 35.8%, encompassing the plain stitch fabric value of 17.8%.

The relationship between the widthwise full (E), elastic (E_1) and delayed (E_2) deformations, and the percentage of the tuck loops (T_n) in the stitch repeat at the width is presented in Figure 5. Figure 6 shows the lengthwise and widthwise contributions of full deformation.

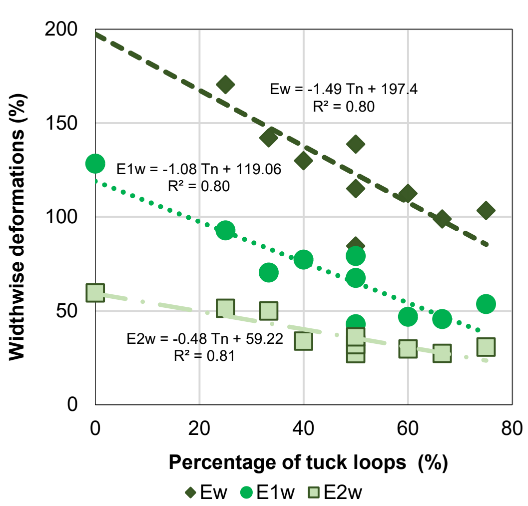


Figure 5: Relationship between the widthwise full (E), elastic (E1) and delayed (E2) deformations, and the percentage of the tuck loops (T_n) in the stitch repeat at the width

The correlation between the full widthwise (E_w), elastic (E_{1w}) and delayed (E_{2w}) deformations, and the percentage of tuck loops (T_n) per width repeat demonstrates a decreasing linear trend (Figure 5). This suggests that an increased number of tuck loops (n) diminishes a fabric's widthwise extensibility. Conversely, the relationship between lengthwise deformations and the percentage of tuck loops (T_n) per width repeat is nonlinear, indicating a more intricate structural response to tuck loop distribution.

The relative contributions of full deformation in both the lengthwise and widthwise directions are depicted in Figure 6, which shows that the deformation ratios confirm the significant influence of the introduction and distribution of tuck loops on fabric anisotropy. The presence and number of tuck loops per width repeat generally reduce the contribution of elastic deformation (E_1/E) to the total deformation in both directions compared with the plain loops, with values ranging from 0.44 to 0.60 in the lengthwise direction and from 0.42 to 0.60 in the widthwise direction, as also mentioned in the paper [16]. This reduction indicates that tuck loops limit the immediate elastic recovery of the fabric, promoting increased structural relaxation and directional dependence in deformation behaviour.

Conversely, the presence and number of tuck loops tend to increase the contribution of residual deformation (E_3/E) relative to the plain loops, with values ranging from 0.09 to 0.21 in the lengthwise direction and from 0.14 to 0.32 in the widthwise direction, reflecting greater permanent set and reduced dimensional stability.

The contribution of delayed deformation (E_2/E) ranges from 0.28 to 0.40 in the lengthwise direction and from 0.26 to 0.35 in the widthwise direction, compared with 0.32 and 0.29 for the plain stitch variant, respectively. These values indicate that tuck loops slightly enhance the viscoelastic component of deformation, allowing gradual stress relaxation and delayed recovery, which contributes to the overall flexibility and time-dependent deformation behaviour of the fabric.

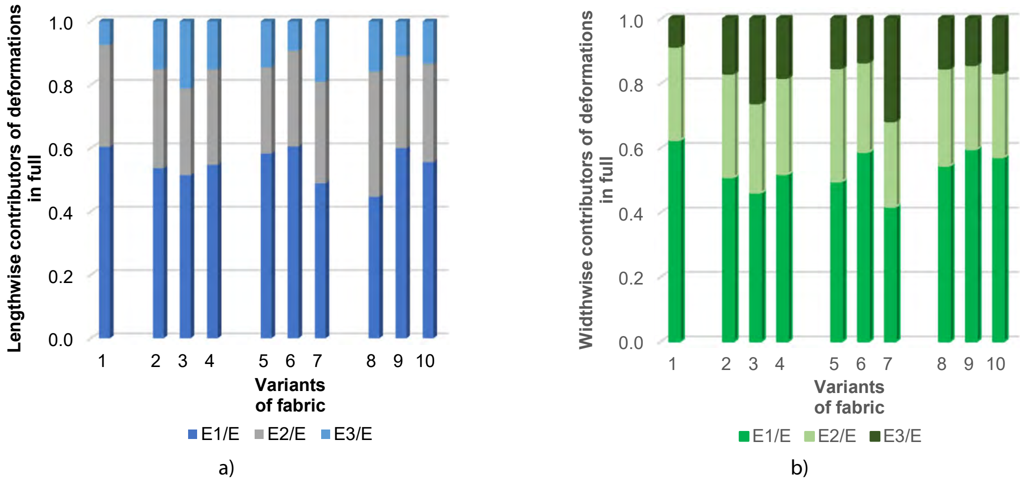


Figure 6: Contributors of elastic (E_1/E), delayed (E_2/E) and residual (E_3/E) deformations in full: a) lengthwise, b) widthwise

Tables 4 and 5 show the t–test statistical results used to determine the lengthwise and widthwise stretch characteristics of independent samples.

A statistical analysis using t-tests (Tables 4 and 5) showed greater differences in widthwise stretch characteristics than in lengthwise stretch characteristics, with a significance level of 0.001. Widthwise full (E), elastic (E_1) and delayed (E_2) deformations of the tuck stitch variants 2, 6, and 10 with 50% tuck loops at the width repeat, compared to the plain stitch fabric (variant 1), exhibit a notable difference, mainly with a significance level of 0.001.

Table 4: Statistical results for the determination of the lengthwise stretch characteristics for independent samples using the t–test

Tested parameter	Value of parameter (t) between plain and tuck stitch variants ($d_f = n_1+n_2 = 8$)			
	E	E_1	E_2	E_3
$t_{1/2}$	15.0 [c]	7.4 [c]	16.1 [c]	13.6 [c]
$t_{1/3}$	7.5 [c]	3.8 [b]	8.1 [c]	8.0 [c]
$t_{1/4}$	5.9 [c]	2.4 [a]	3.6 [b]	6.1 [c]
$t_{1/5}$	4.1 [b]	2.5 [a]	2.8 [a]	4.2 [b]
$t_{1/6}$	5.8 [c]	4.0 [b]	7.9 [c]	5.4 [c]
$t_{1/7}$	5.8 [c]	2.9 [a]	6.0 [c]	5.9 [c]
$t_{1/8}$	3.2 [a]	0.6 [d]	5.3 [c]	8.1 [c]
$t_{1/9}$	7.3 [c]	4.8 [b]	8.9 [c]	4.0 [b]
$t_{1/10}$	4.6 [b]	2.1 [d]	3.1 [a]	5.7 [c]

Legend: [a] 0.05 level of significance; [b] 0.01 level of significance; [c] 0.001 level of significance; [d] no statistically significant difference; d_f degree of freedom

Table 5: Statistical results for the determination of the widthwise stretch characteristics for independent samples using the t-test

Tested parameter	Value of parameter (t) between plain and tuck stitch variants ($d_f = n_1+n_2 = 8$)			
	E	E_1	E_2	E_3
$t_{1/2}$	15.7 [c]	15.3 [c]	12.5 [c]	2.4 [a]
$t_{1/3}$	13.9 [c]	14.5 [c]	12.5 [c]	7.1 [c]
$t_{1/4}$	12.5 [c]	12.1 [c]	10.9 [c]	0.9 [d]
$t_{1/5}$	7.6 [c]	9.2 [c]	3.5 [b]	3.5 [b]
$t_{1/6}$	10.2 [c]	9.7 [c]	8.6 [c]	2.1 [d]
$t_{1/7}$	9.1 [c]	12.6 [c]	10.5 [c]	7.4 [c]
$t_{1/8}$	4.1 [b]	5.8 [c]	2.9 [a]	5.2 [c]
$t_{1/9}$	9.0 [c]	8.6 [c]	7.5 [c]	0.6 [d]
$t_{1/10}$	8.0 [c]	8.3 [c]	7.4 [c]	4.9 [b]

Legend: [a] 0.05 level of significance; [b] 0.01 level of significance; [c] 0.001 level of significance; [d] no statistically significant difference; d_f degree of freedom

4 Conclusion

This study examined the stretch behaviour of nine variants of single-tuck weft-knitted fabrics made from 31 tex ×2 wool/PAN yarn and compared them with the plain stitch fabric. The primary aim was to determine how varying the percentage of tuck loops (T_n) within the stitch repeat influences the stretch properties of the fabrics. The analysis highlights the significant role of loop structure in governing the mechanical behaviour of plain and tuck weft-knitted fabrics.

The plain fabrics exhibited pronounced anisotropy, with widthwise deformation four times greater than lengthwise deformation. Their stretch response was dominated by the elastic component (E_1), indicating strong immediate recovery. Both delayed (E_2) and residual (E_3) deformations were relatively low, demonstrating good dimensional stability. In contrast, tuck stitch variants (2–10) exhibited more balanced deformation between lengthwise and widthwise directions, reflecting the moderating effect of tuck loops on fabric anisotropy.

The presence and proportion of tuck loops in the stitch repeat significantly impacted the stretch behaviour. Lengthwise deformations increased, enhancing fabric extensibility, while widthwise deformations generally decreased, reducing immediate recovery and diminishing the viscoelastic response. Specifically, full, elastic, delayed and residual deformations were higher in the lengthwise direction for tuck stitch fabrics than for plain fabrics, whereas widthwise deformations showed the opposite trend.

The analysis of the deformation components indicated that tuck loops lessen elastic deformation (E_1/E) and increase the residual deformation (E_3/E), suggesting a greater permanent set and reduced dimensional stability. The slight increase in the delayed component (E2/E) suggests enhanced viscoelasticity and stress relaxation. The relationship between deformation components and the percentage of tuck loops per width repeat showed a decreasing trend in widthwise extensibility and a nonlinear response in the lengthwise direction, highlighting the complex structural influence of tuck loop distribution.

Overall, the results confirm that adding and arranging tuck loops facilitates the fine-tuning of the stretch properties of knitted fabrics. By carefully controlling the percentage and placement of tuck loops, textile designers can achieve specific stretch behaviours, optimize recovery and improve dimensional stability, serving as valuable guidance for fabric development and functional textile engineering.

Data availability statement: Since December 5, 2025, the research data has been available at https://zenodo.org/records/17829260 [29].

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