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Impact of yarn type (fiber content), yarn fineness, and structural variation on width contraction of flat-knitted rib derivatives

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ABSTRACT

This study systematically examines width-wise contraction in double jersey knit fabrics produced on a flatbed rib knitting machine, emphasizing the influence of yarn fiber composition, yarn fineness, and structural variations. Fabrics with different structural designs were manufactured using plied yarns composed of 100% cotton, 100% polyester, and polyester-cotton blends (50% for both) across different yarn counts, all knitted under a uniform machine gauge and stitch settings to ensure structural consistency. Subsequently, the wale densities of these samples were measured after dry relaxation, and a modified analytical formula was employed to conveniently calculate the width contraction for rib-based flat-knitted structures. The results revealed that fiber type has a pronounced effect, with cotton-based fabrics exhibiting higher contraction compared to polyester, although the yarn-consisting blend of these fibers showed a statistically non-significant difference in width contraction either with cotton or polyester. Yarn fineness (tex) showed a strong negative correlation with width contraction, as validated by a high co-efficient of determination (R^2 > 0.95), indicating its predictive power. Structural variations, such as jersey type, missing-needle patterns, and rib configurations (such as simple ribs and broad ribs) were found to have notable effects on contraction owing to their impact on wale density and fabric geometry, and statistical analyses confirmed the substantial influence of such structural choices on width contraction. This study provides critical insights into the predictive control of fabric width during the design and manufacturing stages.

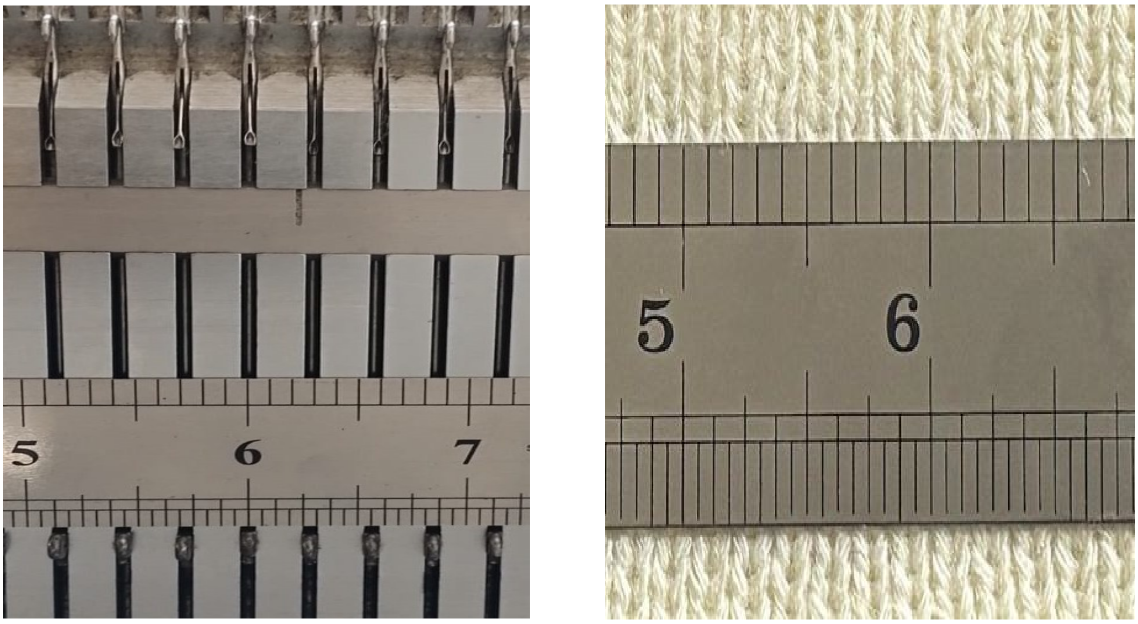
Keywords
Machine gauge,
Wale density,
Double Jersey,
Plain Rib (1×1 Rib),
Fabric contraction

1 Introduction

Knitting, as a method of fabric manufacturing, may be simply defined as interlooping of a series of yarns. Though machine knitting was invented in 1589 by William Lee, it was Lamb & Co. which first launched V-bed machines for producing rib fabrics particularly [1]. Such machines have undergone number of modifications and modernization over the decades; however, the basic V-bed machine is still widely used for producing course gauge fabrics, particularly for fully-fashioned and cut-and-sewn knitwear. The product mix is traditionally dominated by Wool, Acrylic and their blends. Nevertheless, fibers like cotton and spun polyester are gaining significant popularity among consumers for such items in recent times, particularly on sustainability aspect.

Although knit fabrics are wonderful for their unique properties, such as form-fitting, softness and permeability, they are more or less dimensionally unstable. The fabric undergoes deformation as it is generated from the machine until the final stage when the consumer uses the fabric-made garment in his /her daily life. Fabric contraction, particularly width contraction, is the initial deformation of a knitted structure after its formation on a knitting machine. It may be technically distinguished from shrinkage in the sense that the former indicates fabric dimensional change with respect to the machine bed (Figure 1), whereas the latter, for example, width shrinkage indicates width-wise fabric dimensional change from one condition to another such as from a dry-relaxed state to a wet relaxed state [2]. Hossain et al. [3] explained the width-wise contraction of single jersey fabric and derived a necessary formula for calculating the width contraction.

Knowing the fabric's contraction percentage ahead of time, particularly in the width direction, helps estimate the width or wale density of the grey relaxed fabric based on the working width or cut (gauge) of the knitting machine. This estimation can then be used to predict the finished fabric width by applying a finishing factor [4] either as a width ratio or a ratio of geometry constants (Kw) related to the dry-relaxed and finished relaxed states. Alternatively, a knitter can estimate the required cut of the machine from a given fabric sample, if it needs to be developed independently. Thus, knowledge of width contraction may be very helpful for effective knitting saving costs and time. Unfortunately, few studies have so far been attempted to investigate the contraction behavior of a knitted fabric.



(a) (b)

Figure 1: Differences between (a) flat machine gauge (needles/inch) [5] *and (b) fabric gauge (wales /inch)* [6]

Dubied [7] opined that fabric contracts 20% on average when removed from the machine, although the actual rate of contraction depends on fabric construction, stitch cam setting, take-down force, and yarn nature. Havas [8] observed that an increase in the number of active needles during flat knitting results in higher stresses in the course direction of the fabric, thereby increasing the loop width and lowering the loop height, which persists even after dry relaxation. Azim et al [9] studied the properties of some specific rib structures and found that shrinkage percentage increases as the number of needle drops, i.e., missing/inactive needles increases. Similar type of studies was also carried out to observe the effect of rib set-out on fabric width [10] or physical properties [11] of fabric. cotton Incorporated [12] in one of their technical bulletins addressed fabric contraction as construction shrinkage and informed that such characteristics are based solely on fabric construction variables and the ability of the fabric to recover tension during relaxation. Yelina et al. [13] found that course wise stretching in a rib results uneven height/width ratio in the stitch and such dimensional changes are almost independent of yarn type but significantly influenced by ribbing variations. Bukhonka [14] studied the effect of rib set-out irrespective of rib category, i.e. simple or broad rib, and observed that an increase in the number of active needles enhances lengthwise shrinkage and reduces widthwise shrinkage. Hossain et al. [3] conducted research on the width-wise contraction of different cotton single-knit structures and found that such a contraction is negatively correlated to the loop length of the fabric. They also observed that stitch types (knit, tuck and miss), along with their positioning, have a great impact on fabric contraction. Bukhonka and Kyzymchuk [15] studied the influence of rib set-out variations on the structural characteristics and mechanical properties of cotton/flax knitted double jersey fabrics after dry relaxation and four washing cycles. The authors observed an increase in the no. of inactive needles resulted in greater shrinkage and affected the width-wise stretchability. Research works are also available on the dimensional behavior as well as physical and mechanical properties of flat-knitted double-jersey fabrics due to variations in yarn type [16] Yarn count [17–19], fabric structure (knit-tuck based) [20–22] and stitch length [18],[23–25] at different states of fabric. Nevertheless, unlike shrinkage, very few research works could be identified where systematic investigation on width contraction of knitted fabrics were carried out considering yarn as well as structural variations. This study is, therefore, intended to fill a part of this gap by analysing the influence of these factors, thereby providing valuable insights into the optimization of fabric design and production in the context of flat knitting. The present study, thus, aims to explore the effects of yarn type, yarn fineness, and structural patterns on the width contraction of rib-knitted fabric.

Width Contraction

The width of a knitted fabric is generally not equal (in most cases, less) to the working width of the machine bed when it leaves the knitting zone. Width contraction is a measure of the fabric width reduction with respect to the machine bed length, producing a specific fabric. For a circular single-jersey knitting machine with all active needles, the width contraction can be expressed as [3]:

$$Fabric\ Width\ Contraction\ (\%) = \frac{Walse\ per\ Inch - Machine\ gauge}{Wales\ per\ Inch} \cdot 100 \qquad (1)$$

However, in the case of flat knitting, a diverse range of fabrics can be produced by deploying two beds, and missing-needle patterns are usually incorporated. Therefore, Equation (1) must be modified further.

Formula derivation for width contraction of flat-knitted fabric:

The basic way to calculate width calculation may be shown as [3] :

$$FWC\ (\%) = \frac{Length\ of\ the\ needle\ bed - Fabric\ width}{Length\ of\ the\ needle\ bed} \cdot 100 \qquad (2)$$

Where FWC is the fabric width contraction in %. For a rib-knitted fabric produced on a flat knitting machine,

The length of the needle bed, that is, the working width of the machine, can be expressed as

$$Length\ of\ the\ needle\ bed = \frac{Total\ number\ of\ needle\ slots (of one\ bed)}{Manchine\ gauge}$$

or

$$Length\ of\ the\ needle\ bed = \frac{Total\ number\ of\ needle\ slots\ (of\ two\ beds)}{2 \cdot Machine\ gauge} \quad (3)$$

Again, fabric width may be expressed as:

$$Fabric\ Width = \frac{Total\ number\ of\ Wales}{Wales/Inch} \quad (4)$$

As rib structures may contain missing-needle patterns, the total number of wales (TNW) in Equation (4) can be expressed as

$$TNW = TNN \cdot \frac{Total\ number\ of\ loops\ in\ the\ structural\ repeat}{Total\ number\ of\ needle\ points\ in\ the\ structural\ repeat} \quad (5)$$

where TNN – is the total number of needle slots of two beds. With the help of Equations 3, 4, and 5, Equation (2) can be rewritten as

$$FWC(\%) = \frac{\frac{Wales}{Inch} - 2 \cdot Machine\ gauge\ \cdot \frac{Total\ number\ of\ loops\ in\ the\ structural\ repeat}{Total\ number\ of\ needle\ points\ in\ the\ structural\ repeat}}{Wales/Inch} \quad (6)$$

Equation (6) can be used for all types of rib fabrics knitted on a flatbed knitting machine. However, if only one bed of this machine is used to produce a single jersey fabric, Equation (1) will be applicable.

2 Materials and Methods

2.1 Materials

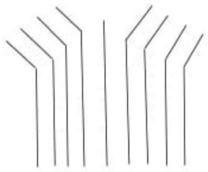
In this study, a laboratory-based manually operated flatbed knitting machine (3.5 gg, single bed length of 36-inch) was deployed to produce fabric samples using rib arrangements of the needles. Three different types of yarns (Cotton, Polyester and Blended) were used as raw materials. The single-yarn notations according to ISO 1139:1973 [26] are listed in Table 1.

Table 1: Single yarn notations

Technical Description		Yarn					
Fiber Content		Cotton				Polyester	Blended (PC, Polyester-50%, Cotton-50%)
Count	Nominal (in Ne)	20	26	30	40	30	30
	Average Actual (in Tex)	29.98 (s=0.13)	23.38 (s=0.13)	19.92 (s=0.04)	15.22 (s=0.08)	19.89 (s=0.04)	19.91 (s=0.08)
Twist per cm		6.83	7.89	8.65	10	9.06	8.92
Direction of Twist		Z	Z	Z	Z	Z	Z

However, because each type of yarn had to be used in plied form (owing to the coarser gauge of the knitting machine), the ultimate designation of yarns can be found in Table 2.

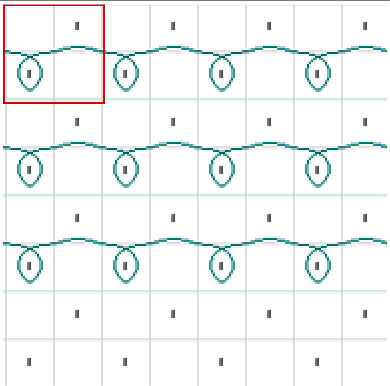
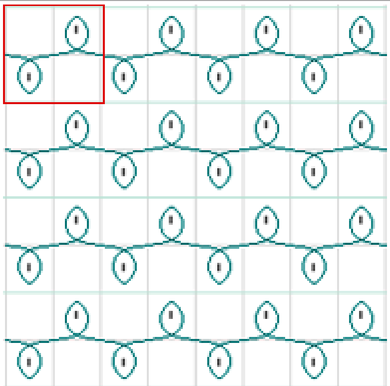
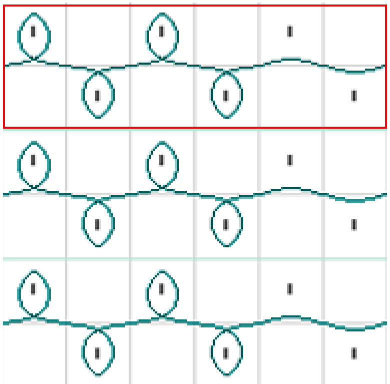
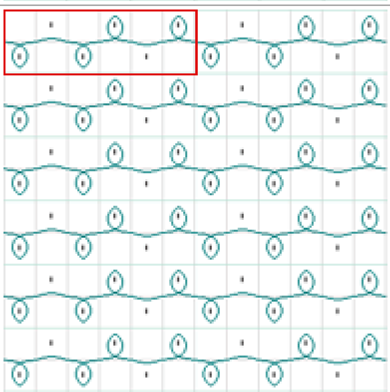
Table 2: Designation of the yarns used for sample production.

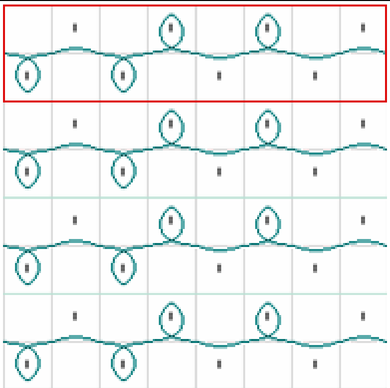
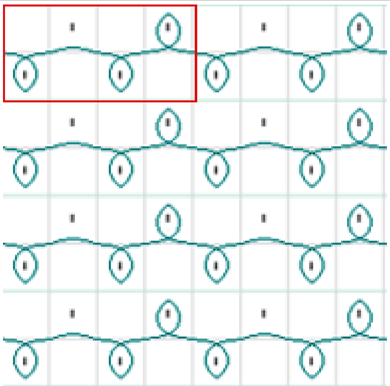
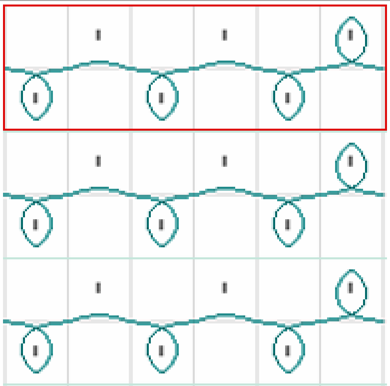
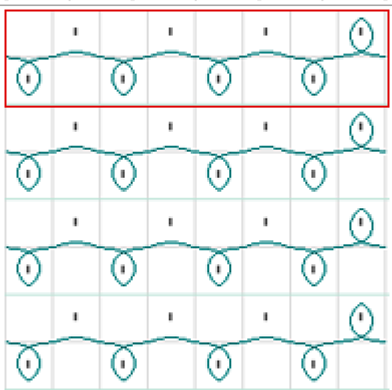
Yarn category and presentation	Yarn type (Fiber content)	Yarn designation	Final count
Plied Yarns 	Cotton (Single yarn nominal count: 20Ne)	Same yarns:9×Tex 29.98 Z 6.83 *9×=Nine yarns are processed parallel together *Tex 29.98: Actual yarn count 29.98 Tex(for single yarn) *Z: Twisting single yarn with Z twist 6.83=Number of twists in 1 cm	270 Tex
	Cotton (Single yarn nominal count: 26Ne)	Same yarns:9×Tex 23.38 Z 7.89	210 Tex
	Cotton (Single yarn nominal count: 30Ne)	Same yarns:9×Tex 19.93 Z 8.65	179 Tex
	Cotton (Single yarn nominal count: 40Ne)	Same yarns:9×Tex 15.22 Z 10	137 Tex
	Polyester	Same yarns:9×Tex 19.89 Z 9.06	179 Tex
	Blended (PC, Polyester-50%Coton-50%)	Same yarns:9×Tex 19.91 Z 8.92	179 Tex

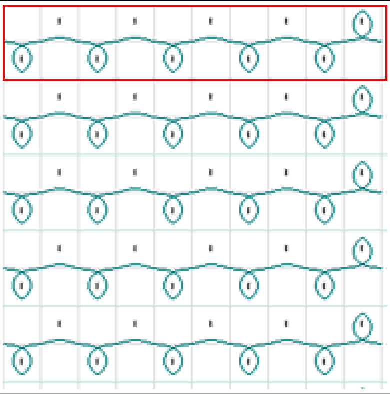
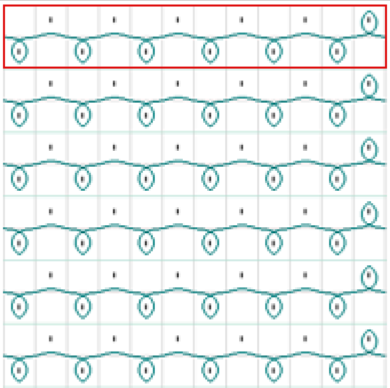
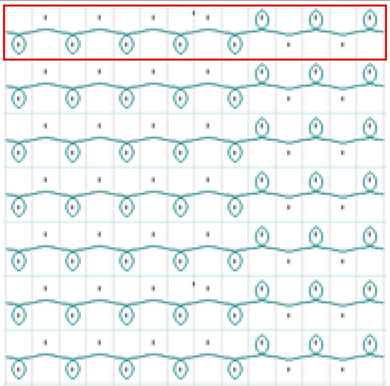
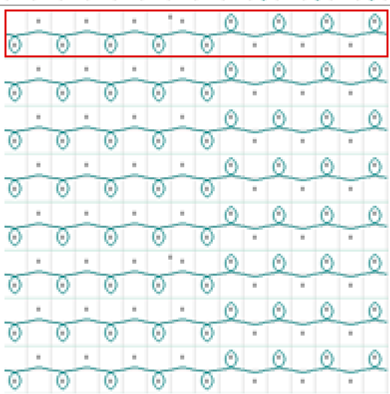
2.2 Sample Production:

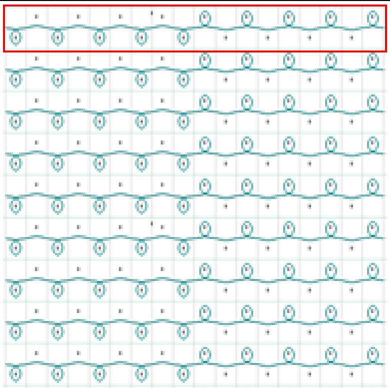
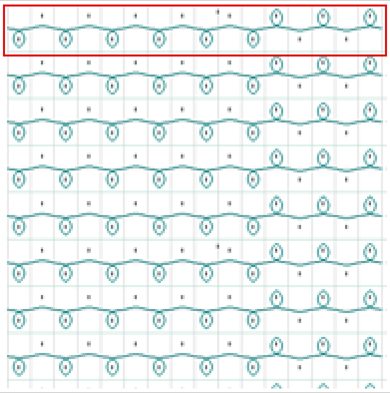
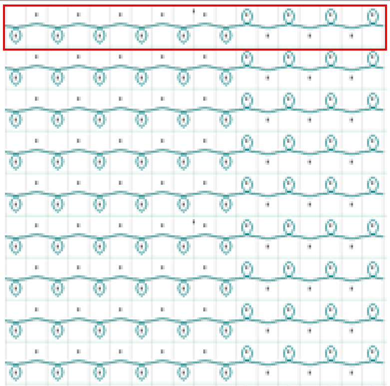
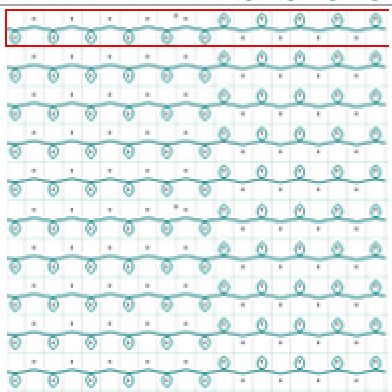
Different rib structures were produced using the same stitch cam setting. Subsequently, plain jersey was made by deactivating needles of a bed, i.e., the back bed. In addition to using yarn packages of almost the same size, special care was taken to avoid yarn tension and to reduce tension variations during the knitting operation. A total of 22 samples were developed, including 17 different structures produced from cotton, polyester, and blended (Polyester-50%, Cotton-50%) yarns. The structures and notation diagrams are listed in Table 3. Each sample was around 04 (Four) meter in length and the full bed length was deployed to produce the samples.

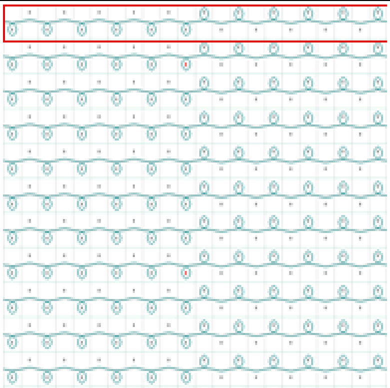
Table 3: Developed fabric samples.

Structure Type	Notation Diagram	Developed sample (Effect side)	Developed sample (Reverse side)
Plain Jersey			
1X1 Rib			
Skeleton 1x1 Rib			
2x2 Swiss Rib			

Structure Type	Notation Diagram	Developed sample (Effect side)	Developed sample (Reverse side)
2x2 English Rib			
2x1 Rib			
3x1 Rib			
4x1 Rib			

Structure Type	Notation Diagram	Developed sample (Effect side)	Developed sample (Reverse side)
5x1 Rib			
6x1 Rib			
5x3 Rib			
5x4 Rib			

Structure Type	Notation Diagram	Developed sample (Effect side)	Developed sample (Reverse side)
5x5 Rib			
6x3 Rib			
6x4 Rib			
6x5 Rib			

Structure Type	Notation Diagram	Developed sample (Effect side)	Developed sample (Reverse side)
6x6 Rib			

2.3 Measurement of fabric parameters

After each fabric sample was knitted, it was carefully removed and placed in a relaxation chamber. All samples were relaxed on a flat surface for approximately 120 hours. The dry relaxation temperature was approximately 27°C and the relative humidity was approximately 67%. After relaxation, the wales per unit width of each sample were measured following BS 5441:1988 [27]. A ruler was used to count wales per inch (WPI) or wales per 2.54 cm while maintaining a measuring distance of approximately 10 cm for each reading. Finally, the loop length of each sample was measured using a crimp tester following the same standard to verify the structural consistency.

3 Results and Discussion

The fabric width contraction % was calculated using equation (6) for all rib fabrics and equation (1) for a single jersey fabric. The calculated values of the width contraction along with the measured WPI and loop length values are shown in Table 4. These are shown through a number of sample groups (S-1 to S-5) to facilitate clear data analysis.

Table 4: Width contraction of different samples produced

Sample Group	Fabric Type	Yarn	Average Loop length (cm)-up to 1 decimal place	Average wales per inch,WPI or wales per 2.54 cm	Width contraction (WC%)
S-1	1×1 Rib	Cotton, 179 Tex	1.2 (s=0.018)	13.4(s=0.52)	47.7
	1×1 Rib	PC,179 Tex	1.2(s=0.016)	12.9 (s=0.57)	45.64
	1×1 Rib	Spun Polyester,179 Tex	1.2 (s=0.016)	12.5 (s=0.53)	43.91
S-2	1×1 Rib	Cotton,270 Tex	1.2 (s= 0.015)	11.9 (s=0.32)	41.17
	1×1 Rib	Cotton,210 Tex	1.2(s=0.016)	12.5(s=0.53)	44
	1×1 Rib	Cotton,179 Tex	1.2 (s= 0.018)	13.4 (s=0.52)	47.7
	1×1 Rib	Cotton,137 Tex	1.2 (s= 0.013)	14.3 (s=0.48)	51.05
S-3	Plain Jersey	Cotton,179 Tex	1.2 (s= 0.017)	5.9 (s=0.32)	40.68
	1×1 Rib	Cotton,179 Tex	1.2 (s=0.018)	13.4 (s=0.52)	47.7
	Skeleton 1×1 Rib	Cotton,179 Tex	1.2 (s=0.011)	15.6 (s=0.84)	70.06
	Swiss Rib	Cotton,179 Tex)	1.2 (s=0.015)	18.2(s=0.63)	74.34

	English Rib	Cotton,179 Tex	1.6 (s= 0.012)	20.2(s=0.63)	82.67
S-4	2×1 Rib	Cotton,179 Tex	1.2 (s=0.016)	13.7 (s=0.18)	61.68
	3×1 Rib	Cotton,179 Tex	1.2 (s=0.017)	12.1 (s=0.32)	61.40
	4×1 Rib	Cotton,179 Tex	1.2(s= 0.021)	10.2 (s=0.42)	57.11
	5×1 Rib	Cotton,179 Tex	1.2 (s= 0.028)	8.9 (s=0.32)	52.81
	6×1 Rib	Cotton,179 Tex	1.2 (s=0.024)	7.8(s=0.32)	47.7
S-5	5×3 Rib	Cotton,179 Tex	1.2(s= 0.016)	17.9(s=0.32)	77.65
	5×4 Rib	Cotton,179 Tex	1.2(s=0.014)	21(s=0.47)	81.24
	5×5 Rib	Cotton,179 Tex	1.2 (s= 0.017)	26.3(s=0.48)	85.21
	6×3 Rib	Cotton,179 Tex	1.2 (s= 0.013)	16(s=0.67)	75.37
	6× 4Rib	Cotton,179 Tex	1.2 (s= 0.020)	20.2(s=0.42)	80.74
	6×5 Rib	Cotton,179 Tex	1.2 (s= 0.022)	24.1(s=0.57)	84.02
	6× 6 Rib	Cotton,179 Tex	1.2 (s= 0.019)	29.6(s=0.70)	87.09

Effect of yarn type on width contraction (Evaluation of sample group, S1)

The influence of yarn type, specifically fibre composition, was evaluated by comparing 1×1 rib knitted fabrics produced from cotton (natural cellulosic), spun polyester (synthetic), and cotton-polyester blend yarns. A bar diagram (Figure 2) was used to analyze the resultant contractions.

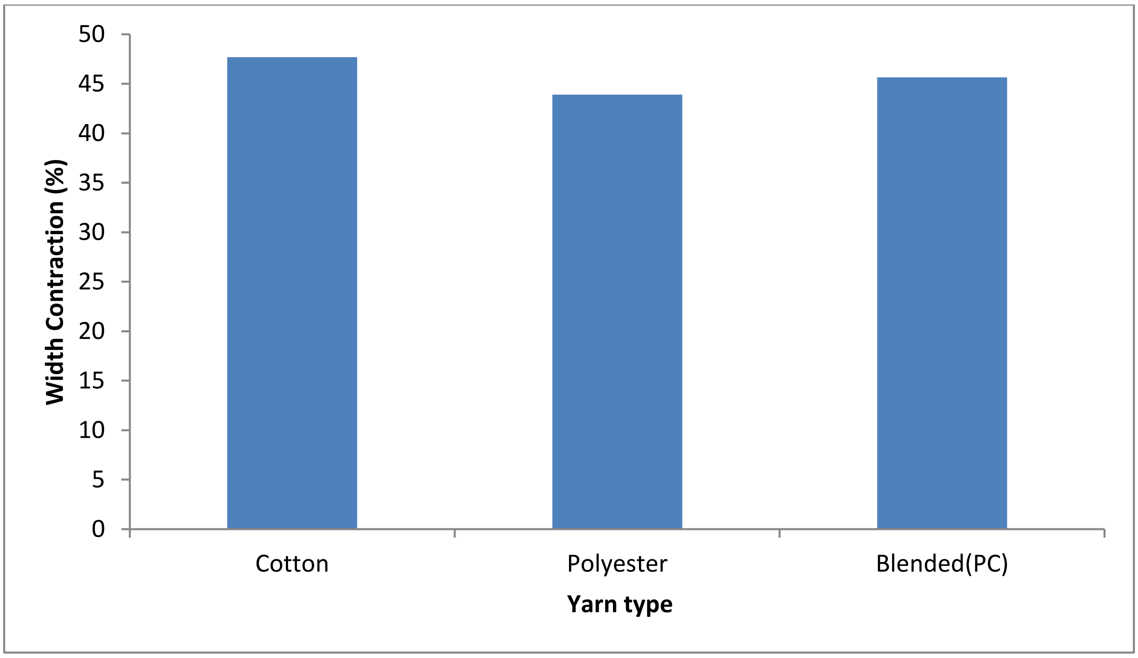


Figure 2. Variation in WC (%) due to yarn type (fibre content) for 1×1 Rib.

It can be observed that cotton 1 × 1 rib showed a higher contraction% among the three fabrics, and polyester 1 × 1 rib showed the lowest. Alternatively, it can be expressed that spun polyester knitted fabric generates a higher fabric width than cotton or PC fabric for the same needle bed length and knitting machine setting. This may be attributed to the fact that polyester has a higher flexural rigidity than cotton [28], which results in less bending to the third dimension during relaxation. However, the mean differences among the width contraction values were not very high, i.e., less than 4% in each case (Table 4). So, a two-sample t-tests for sample data were carried out to determine whether these differences were statistically significant. The obtained results are presented in Table 5.

Table 5: Test of significance for width contraction due to yarn type variation.

Statistical parameters for a two samples t-test	Width contraction (%) for Cotton 1×1 Rib, as calculated from WPI values (a)	Width contraction (%) for Spun Polyester 1×1 Rib, as calculated from WPI values (b)	Width contraction (%) for Blended1×1 Rib, as calculated from WPI values (c)
No. of observations	10 (50,50,46.15,50,46.15, 46.15,46.15,50, 46.15and 46.15)	10 (46.15,41.67,41.67,46.15,41.67,46.15, 41.67,41.67,46.15 and 46.15	10 (46.15,46.15,41.67,41.67,46.15,46.15,50,46.15, 46.15 and 46.15)
Mean	47.7	43.91	45.64

Absolute Mean Difference [between (a) and(b)]	3.79
t-value [for (a) and(b)]	3.87
p-value [for (a) and(b)]	0.0037
Absolute Mean Difference [between (b) and(c)]	1.73
t-value [for (b) and(c)]	1.61
p-value [for (b) and(c)]	0.1418
Absolute Mean Difference [between (c) and(a)]	2.06
t-value [for (c) and(a)]	2.07
p-value [for (c) and(a)]	0.0683
Critical value	2.10

From Table 5, it can be observed that while comparing the width contractions of cotton and polyester knitted 1×1 rib fabrics, the null hypothesis can be rejected [t-value(t-statistic) is 3.87, i.e., more than the critical value of 2.10, as obtained from a t-table [29]]; therefore, a statistically significant difference exists between the width contractions of cotton and polyester knitted 1×1 rib fabric based on the 95% confidence level (p-value=0.003788769).However, the differences in width contractions for polyester and PC, as well as PC and cotton, are not statistically significant as the null hypotheses for these two groups cannot be rejected. The reason is that the obtained t-values are 1.61 and 2.07 respectively, i.e., t-value is less than the critical value of 2.10 in each case.

Effect of yarn fineness on width contraction (Evaluation of sample group, S2):

To determine the effect of yarn fineness on width contraction, the width contraction values obtained for different counts of cotton yarn were plotted on a scatter diagram. Figure 3 clearly shows a strong negative correlation (Co-efficient of determination, R^2 was greater than 0.95) between yarn count (Tex) and width contraction.

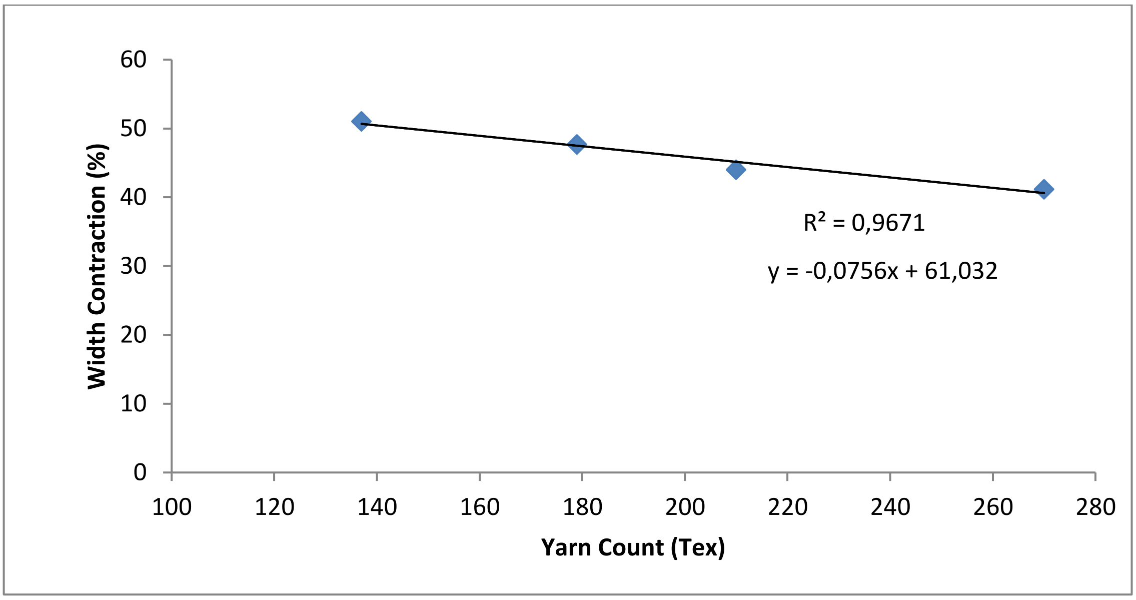


Figure 3: Yarn count (Tex) vs. Width Contraction (%) with least square trend line.

Moreover, using the regression equation, one may predict the changes in width contraction due to variations in the yarn count. The influence of the yarn count on fabric width contraction can be understood through its effect on fabric tightness. The fabric tightness of a rib fabric can be calculated using the following equation proposed by Wolfaardt [30]:

$$K = n\frac{\sqrt{T}}{l} \quad (7)$$

Where K= Tightness factor of the fabric, n= Number of loops in the structural-knit-cells, T=Yarn count (tex), l and l=loop length (in cm or mm).

Equation (7) indicates that with an increase in yarn count (Tex), there is a corresponding increase in the tightness factor, resulting in reduced space for loop movement during relaxation. Consequently, the width contraction is inversely related to yarn fineness (Tex).

Effect of active needle bed and needle- missing on width contraction (Evaluation of sample group, S-3):

The impact of the active needle bed was assessed by knitting a plain jersey fabric using cotton yarn alongside a 1×1 rib, followed by the calculation of width contraction. Again, to observe the effect of missing needles, the width contraction of the Skeleton 1×1 rib (a derivative of a 1×1 rib with a missing wale at every third needle point) was compared with the 1×1 rib. Moreover, to investigate the influence of the number of needles missing in a designated structure (here, 2×2 rib) the width contraction values of the Swiss Rib and English Rib were compared with one another. All three comparisons are shown in Figure 4.

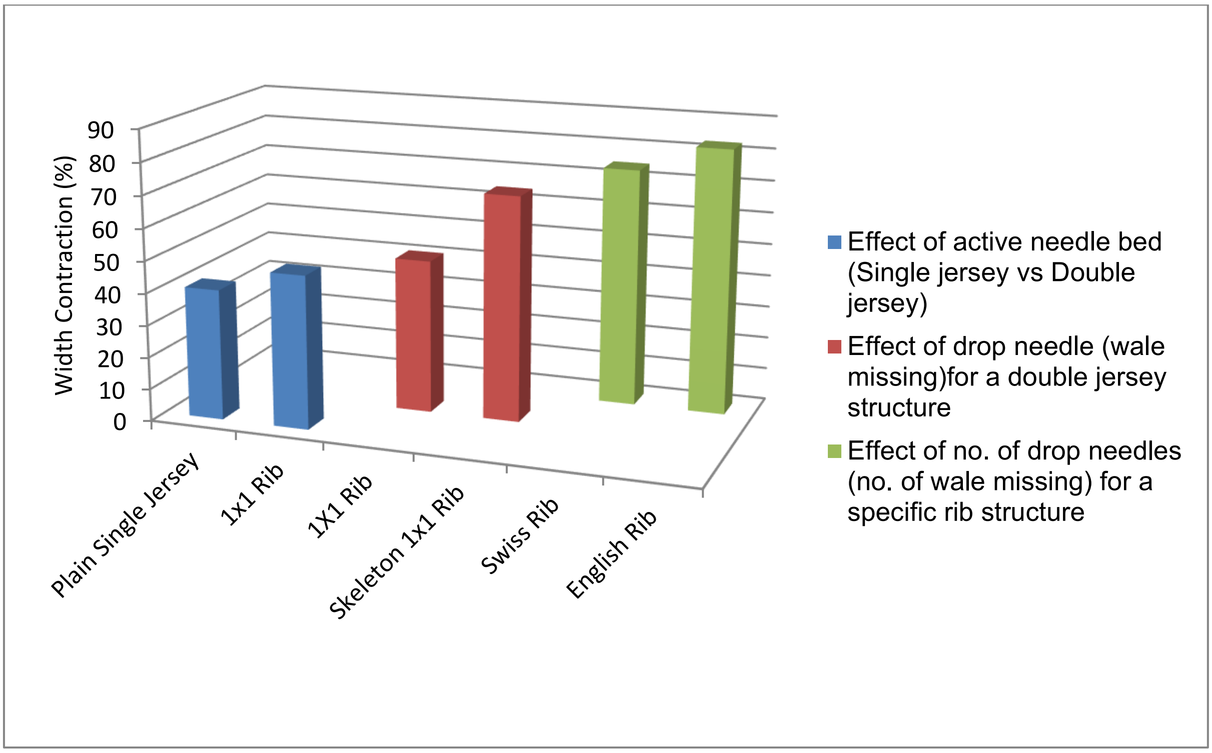


Figure 4: Effect of active needle bed and needle- missing on width contraction.

From Figure 4 it may be observed that 1×1 rib has greater width contraction than plain jersey This can be attributed to the fact that 1×1 Rib is formed by reversing alternating stitches which collapses width-wise into a concertina-like structure upon relaxation [31]. Thus, stitch-reversal results in greater width-wise contraction in plain ribs. Again, if a missing needle pattern is created through needle drops, this facilitates bringing nearby wales close together [32], increasing WPI, and thus enhancing width contraction. Hence, the Skeleton 1×1 rib showed a greater width contraction than the 1×1 rib. Furthermore, the number of missing wales (due to needle-missing) in a designated structure enables it to be deformed into the third dimension with greater ease. Hence Swiss Rib (a 2×2 rib with one wale missing in the structural repeat) shows less width contraction than the English Rib (a 2×2 rib with two wales missing in the structural repeat). The findings also align with the observations made by Bukhonka and Kyzymchuk[15] regarding the structural characteristics of double-knit fabrics in a dry relaxed state.

Effect of structural variations (for simple ribs and broad ribs) on width contraction

(Evaluation of sample group, S-4 and S-5):

A simple rib, by definition, contains more than one plain wale but only one rib wale. Alternately, a broad rib has groups of three or more adjacent wales of the same type, either face (plain) or back(rib) [33]. From Figure 5, it can be observed that, as no. of the plain wale increases in simple ribs, the width contraction decreases. The R-square (R^2) value of 0.94 also indicates a strong correlation between the number of plain wales and the width contraction of simple ribs. Besides the regression equation reveals a projected 3.65% reduction in width contraction on simple ribs as the no. of plain wale is increased by 1 (one).

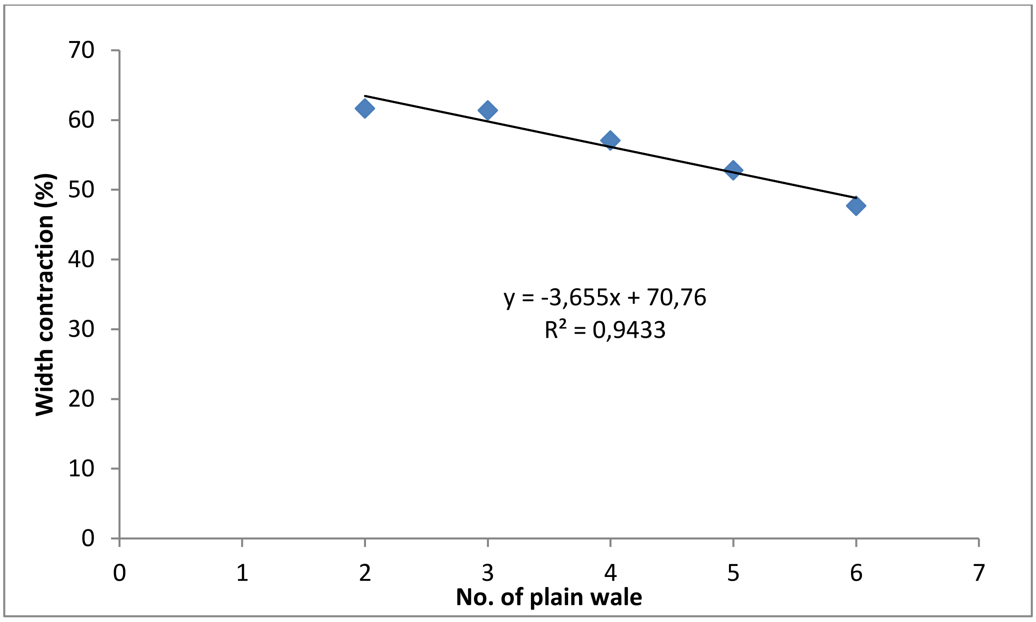


Figure 5: Number of plain wales vs. Width contraction (%) with least square trend line for simple ribs, i.e.,2×1, 3×1, 4×1, 5×1 and 6×1 ribs.

The phenomena of width contraction for simple ribs may be explained by the fact that more no. of plain wales makes it difficult for the rib wale to pull fabric cells inward into the third dimension during relaxation. A typical example of such a phenomenon is illustrated in Figure 6.

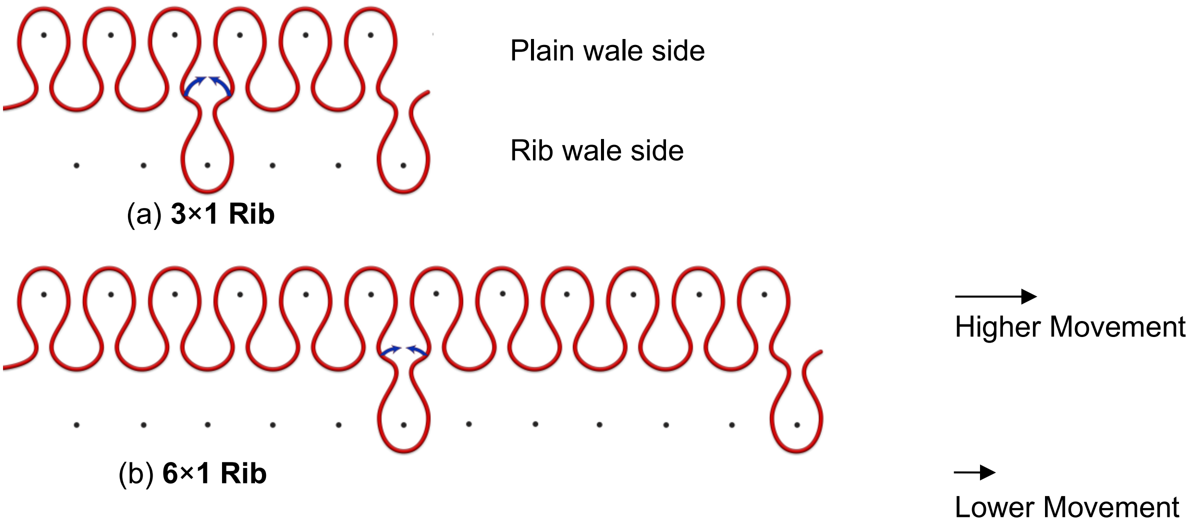


Figure 6: Width contraction through relaxation movement of fabric cells:(a) 3×1 Rib and (b) 6×1 Rib.

Wales of the developed fabric are shown in Figure 7.

(a) (b)

Figure 7: Top view along wales of relaxed simple ribs: (a) 3x1 Rib (b) 6x1 Rib.

On the other hand, when no. of rib wales becomes higher in the structural repeat (in the case of broad ribs), the recovery movement to relaxation also becomes greater by the adjacent rib wales. Moreover, the corresponding needle-missing or needle drop) effect on the plain wale side also enhances a higher wale density (Figure 8). Hence width contraction grows higher for broad ribs (with same no. of adjacent plain wales) having a greater number of rib wales (Figure 8).

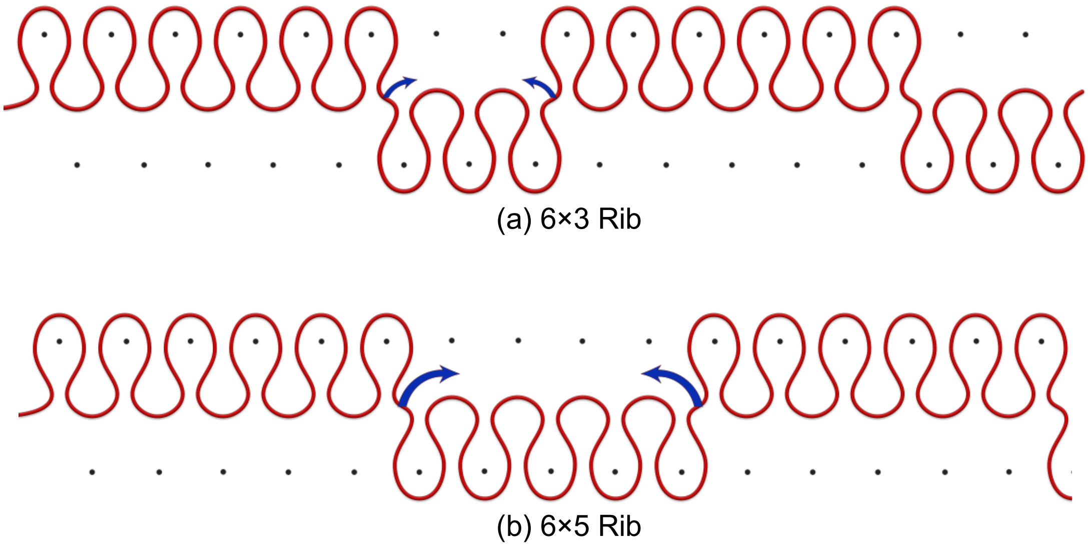


Figure 8: A typical example of contraction phenomena for broad ribs depicted through notational diagrams: (a) 6x3 Rib and (b) 6x5 Rib

Figure 9 and Figure 10 are two examples, showing the influence of structural variations on the width contractions of the broad ribs.

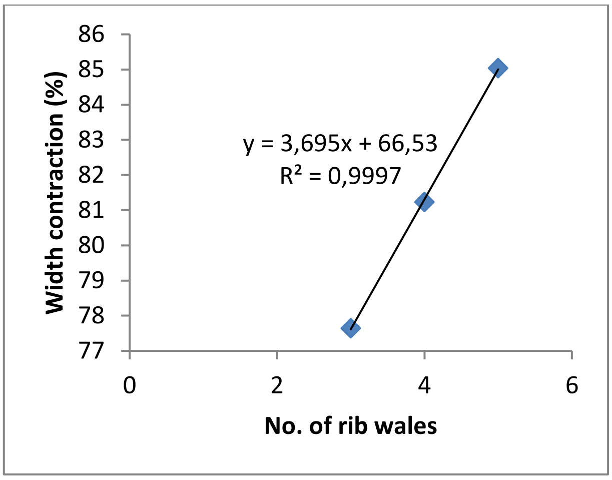


Figure 9: Number of rib wale vs. Width Contraction (%) with least square trend line for broad ribs having number. of adjacent plain wale as 5, i.e.,5×3,5×4 and 5×5 Ribs.

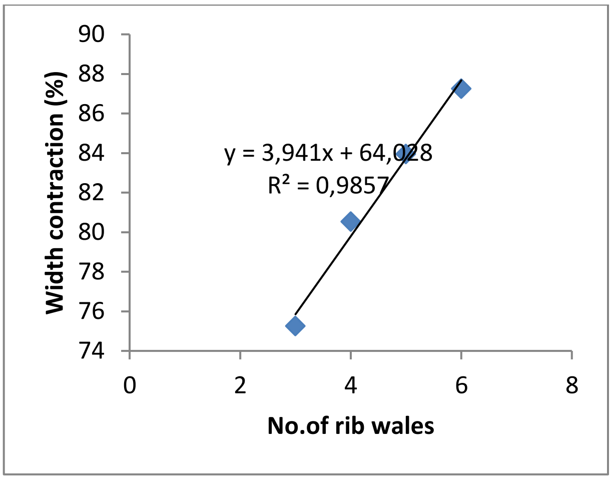


Figure 10: Number of rib wale vs. Width Contraction (%) with least square trend line for broad ribs having number. of adjacent plain wale as 6, i.e.,6×3, 6×4,6×5 and 6×6 Ribs.

In both cases, the R^2 value was higher than 0.95, indicating a strong correlation between no. of rib wales and width contraction. Also, the regression equations (from Figure 9 and Figure 10)) indicate estimated changes in width contraction (due to rib wale increment by 1) by +3.7% and +3.9% for the experimental samples of two different broad rib groups (5-plain wales based and 6-plain wales based) respectively. Two real fabric images (6×3 and 6×5 ribs) are shown in Figure 11 to compare the broad rib width contractions in visual form.

(a)

(b)

Figure 11: Top view along wales of relaxed broad ribs : (a) 6×3 Rib and (b) 6×5 Rib.

Limitations of the study:

This research is subject to a few limitations. The width contraction values obtained here were typically after dry relaxation. These values might differ if the experimental fabrics were subjected to wet or full relaxation treatment. The relaxation degree of the fabric, particularly of a hydrophilic nature, increases after soaking, with associated dimensional deformation [34]. Therefore, the generalization of the obtained results is questionable from a practical perspective. However, a prior determination of the width factor [4], i.e., the ratio of the wale densities in dry and wet/fully relaxed states, may help in a good estimation of the fabric width of wet/fully relaxed fabric. Nonetheless, wet/fully relaxed fabric parameters should be determined periodically to verify the results derived from dry-relaxed fabric parameters. Additionally, the experimental structures lack tuck loops, which would enable the identification of the influence of tuck-based rib structures on width contraction. In future examinations, additional rib structures (such as knit-tuck and knit-tuck miss-based) will be tested at different relaxation states to explore the broader spectrum of width contraction in rib fabrics.

4 Conclusion

This study provides a comprehensive analysis of the width-wise contraction behavior of double jersey knit fabrics produced on a flatbed knitting machine, considering the effects of yarn fiber content, yarn fineness, and structural design variations. For this purpose, a universal equation has been developed and then applied to calculate width contractions for some experimental samples knitted with different material properties and structural architect. It was found that both cotton and polyester ribs contracted more than 40% widthwise after dry relaxation where cotton ribs showed somewhat higher contraction. However, the blended yarn (cotton and polyester) ribs did not show statistically significant differences in width contraction from cotton or polyester. Additionally, it was also observed that width contraction decreased for ribs knitted with coarser yarns. Such contraction also showed higher value in plain rib than plain jersey structure. Moreover, structural modification by incorporating wale missing pattern enhanced width contraction. Furthermore, the arrangement of plain and rib wales on a rib structure were also found as an influencing factor for the width contraction behavior. In this study, simple ribs exhibited less contraction as the number of plain wales increased whereas broad ribs exhibited more contraction as the number of rib wales increased. These findings thus confirm that width contraction of a flat-knitted rib is influenced by yarn fibre content, yarn fineness and structural design.

The implications of these findings are particularly valuable for industrial applications where control over the fabric dimensions is critical. The derived contraction model enables pre-knitting estimation of the relaxed fabric width based on known machine specifications and fabric design inputs. This predictive capability supports improved planning in the fabric layout, minimizes post-processing adjustments, and enhances consistency in mass production.

Although this investigation was conducted using a fixed machine gauge, the methodology may be inherently adaptable to flat machines of other gauges too. The analytical approach may be extended more widely across flat knitting operations by recalibrating the formula inputs to reflect the different machine/needle bed settings. Researchers may also verify the impact of natural or synthetic yarns on width contraction more elaborately by knitting fabrics with yarns other than cotton or polyester. So, the scope for further research on width contraction remains. This study, thus, advances the understanding of dimensional behavior in double-jersey rib structures and provides a replicable, data-driven tool for optimizing fabric design and production efficiency for a V-bed knitting machine.

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