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Investigation into shrinkage of stretchable denim fabric and its consumption in marker making by varying drying temperatures

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KEYWORDS

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ABSTRACT

This investigation was carried out to minimize Cotton and Cotton–polyester stretchable denim fabrics consumption for garment development through marker making. It was achieved by controlling fabric shrinkage by reducing drying temperature after washing in fixed processing time, without compromising properties of denim; Tensile strength, Stretch (growth and recovery at constant and cyclic loading) and colour strength (K/S) of required shade. warp faced 3x1 and 2x1 denim containing elastin were constructed and then washed using same recipe as per industrial practice however drying temperatures were set at 50oC, 60oC and 70oC, separately. After measuring shrinkage and evaluating tensile strength, Stretch, Growth and recovery at constant and cyclic loading and colour strength (K/S) using standard test methods; trouser marker layout was developed by employing Gerber technology to investigate fabrics consumption. The obtained shrinkage % demonstrated a significant coefficient of determination (R2=0.9931) against drying temperatures. Relation of tensile strength, colour strength and growth were insignificant however stretch, growth and recovery at static and cyclic loading were significantly affected by changing temperatures. Average shrinkage % of stretchable denim fabric was 1.71% in warp and 8.24% in weft at 50oC. It increased to 12.05% in weft at 60oC however remained same in warp while against 70oC it was 1.82% in warp and 14.08% in weft. 10 minutes drying time was kept same for selected drying temperatures. It was found that fabric consumption reduced to 1.25 m per trouser from 1.32 m per trouser by setting drying temperature at 50oC. Present research work provides guideline to denim industries to process stretchable denim at lower drying temperature i.e., 50oC because it not only reduced consumption of elastin containing denim fabric, but it also makes process cost effective as well as environmentally friendly.

1. Introduction

Demand of denim has been growing worldwide due its comfort, durability, fashion, easy wear and serviceability [1, 2]. Stretchable denim articles are more popular in fashion and casual wear however the development requires well working to deal with shrinkage of stretchable denim fabrics which changes fabric consumption especially in particular marker style [3, 4].

There is usually around 98% cotton and 2% elastic blend in stretchable denim fabrics that are very popular because of comfort and ease of movement. Denim fabric is processed before making garment; and fabrics are subjected to chemical treatment and drying process [5]. Due to wet processing, application of chemicals and drying using hot air, shrinkage of the denim fabric varies in warp and weft directions. Mostly denim shrinks in weft [6, 7] but some studies reported more shrinkage in warp either; 15.5% in warp and less than 8% in weft [8]. Shrinkage varies in different processes which include ozone treatment, Super White Washing Process and even during different washing techniques [6, 9]. Most of the studies deal with shrinkage of stretchable denim with emphasis on washing techniques and one of the studies investigated shrinkage on different washing temperatures also. It is very important to investigate shrinkage of stretchable denim on different drying temperatures too because elastin shrinks more in hot environment. An investigation reported -0.9% and -1.9% shrinkage in warp and weft respectively at 35°C, however with gradual rise of process temperature; it increased to -3.1% and -4.7% at 80°C [7].

There is a requirement of preparing patterns before transforming fabrics into garments. It is important to measure denim shrinkage in the phase of clothing design; otherwise, measurements of readymade articles would not be same as designed before manufacturing.

Marker making department is one of the key departments in the garment manufacturing industry to control the fabric consumption for a particular garment style. Marker making software generates marker for optimized fabric consumption of particular garment style [10-12]. Development of an efficient marker layout of any garment article is dependent on the article pattern and grading scheme [12] especially consumption of elastin denim fabric is a challenge for denim industry due to variable washing processes for development of specific shades and styles. Washing process imparts value addition attributes to the final product [6].

Main problem while making the patterns is that we have to count with shrinkage. Fabrics are generally subjected to considerable tension during weaving, especially in the warp direction. This stretches fabric further in subsequent finishing processes and because of stretching, stresses temporarily set in the fabric and the fabric becomes dimensional instability after going through wet processing [8]. Among different processes involved in denim garments manufacturing, washing conditions are considered as the most important process parameters. Garments shrink during washing operations [8]and hence fabric consumption may vary. The dimensional stability of stretch denim fabrics differs with different washing processes. Properties like tensile strength, tear strength and colour fastness properties also dependent on type of washing carried out to achieve particular shade and style [6]. Shrinkage of stretchable denim in warp and weft directions also varies upon changing processing parameters [6]. The highest shrinkage in weft direction was reported after treating denim fabric with heavy enzyme stone wash and bleaching [6]. Literature search revealed that different shrinkage values were obtained against various washing techniques. The shrinkage of stretchable denim is linked to the extent of variation in its structure after washing [13].

It is difficult to predict shrinkage of elastin denim fabrics after a specific process. Like one of the studies reported significant variation in shrinkage after ozone treatment [8]. Whereas spandex fibre shrinks more in hot environment in the garments during washing and drying processes [7].

Different researchers focused on the recipe of denim washing to impart special effects however consideration of particular recipe to take into account shrinkage for estimation of fabric consumption is still under investigation [2, 10]. analysis of denim fabrics before and after washing [11] has been carried out by studies however impact of the conjoined effects of washing and drying parameters on Cotton and Poly-Cotton stretchable denim fabrics ‘shrinkage, properties and consumption was not studied before. Different studies reported different drying temperatures i.e. 90ºC, 75ºC and 70ºC [6, 8, 9] so there is no fixed temperature for drying stretchable denim fabrics.

In this investigation, effects of drying temperatures on denim shrinkage, different properties and ultimately on marker efficiency for fabric consumption was studied, after doing enzymatic washing. 100% Cotton and Poly-Cotton Stretchable denim fabrics were weaved, 2/1 and 3/1 in both materials. Fabric samples prepared were dried separately after washing at 50ºC, 60ºC and 70ºC temperatures. Shrinkage of all samples were measured using standard test methods along with Tensile strength, Colour Strength (K/S), Stretch, Growth and Recovery on Static and cyclic loading evaluation. Trouser as an article was selected. Influence of fabric shrinkage on efficient maker layout for 400 pieces of trouser was investigated after washing and drying at selected temperatures.

Aforementioned drying temperatures are not fixed by the relevant denim fabrics industries after carrying out enzymatic washing that's why it is crucial to explore the effect of drying denim fabrics properties and consumption at lower drying temperatures i.e. 50ºC, 60ºC and 70ºC. If desired results are obtained so research findings can be proposed to the denim industries for sustainable solution to moderate consumption of resources and avoid fabric wastage to develop particular article; by controlling shrinkage through lower drying temperature at fixed time without compromising required properties.

2. Materials and Method

2.1 Material

Warp faced 3x1 and 2x1 stretchable denim fabrics of Elastin Cotton and Elastin Poly-Cotton (PC) were constructed. As per standard method DIIN EN 12127 fabric specifications were evaluated and listed in Table I.

Table 1

Specification of warp faced weave denim fabric

Serial No	Sample detail	Fabric weave	Average fabric weight (g/m^2)
1	Cotton elastin	Warp faced 3x1	270
2	Cotton-polyester elastin		268
3	Cotton elastin	Warp faced 2x1	260
4	Cotton-polyester elastin		259

2.2 Sample Preparation Method

Cotton elastin and PC elastin denim fabrics are mostly indigo dyed. Dyeing process reduces softness of the denim fabrics. Washing not only removes unfixed dyes but also improves fabric feel, aesthetics and above all, makes it wearable.

To desize denim fabrics, Bascillus and Aspergillus species amylase are mostly employed by the industries. In the assistance of gelatinization and swelling agent, enzymatic breakdown occurred and formed protein by hydrolysing starch of elastin denim fabric [12]. In addition, alpha amylase converts large dextrins into smaller dextrins chain.

Colour fading effect is achieved by hypochlorite bleaching which also improves fabrics appearance. By adjusting concentration of chlorine in sodium hypochlorite solution, temperature and pH desired colour fading effect can be attained. 12% chlorine content is recommended for 40g/L sodium hypochlorite at 9-10 pH [14]. In this study, Cotton and PC elastin denim fabrics were desized and bleached using bascillus species amylase and sodium hypochlorite respectively.

Samples prepared of size 100cm x100 cm, were processed in washing machine (3 kg). Recipe and related parameters are presented in Table II, from Desizing to Finishing keeping liquor ratio 1:7.

Table 2

Washing recipe and parameters

Process	Chemical Qty.	Time, minutes	Temperature, ºC	pH
De-sizing	Amylase, 60 gram Bio polishing enzyme, 60 gram	20.00	45.00	7.50
One wash				
Bleach	Sodium Hypochlorite, 700ml	5.00	Ambient	10.00
One wash				
	Sodium, 200 gram	5.00	Ambient	7.50
One wash				
	Softener, 500 gram	3.00	Ambient	7.50
One wash				

Experimental model developed for this study is shown in Table III. Washed Cotton and PC elastin denim samples were divided into three lots. Each lot contained 25 elastin denim fabric samples. Prepared lots were dried at 50ºC, 60ºC and 70ºC temperatures for 10 minutes. As per ISO 3759 standard, average shrinkage at three different temperatures of Cotton and PC elastin denim fabric samples were evaluated and shown, see Table IV to Table IX. Five replicates were used. Each replica was tested for the number of specimens as mentioned in the standard test procedures of tensile strength, Stretch, Growth and recovery at constant and cyclic loading, shrinkage and colour strength (K/S).

2.3 Experimental Model

Table 3

Experimental model

Fabric	Sample Detail	Drying temperature (°C)	Code
Twill 2x1	Cotton elastin	50	A1
		60	A2
		70	A3
	Cotton-polyester elastin	50	B1
		60	B2

		70	B3
Twill 3x1	Cotton elastin	50	C1
		60	C2
		70	C3
	Cotton-polyester elastin	50	D1
		60	D2
		70	D3

Aforementioned Cotton elastin and PC elastic fabrics were selected in 2x1 and 3x1 twill weaves then washed and then dried at 50°C, 60°C and 70°C. Processed fabrics were given specific codes for the identity and simplicity. For Cotton elastin 2x1 twill weave fabric sample, code was A and numbers 1, 2 and 3 were assigned for the temperatures 50°C, 60°C and 70°C respectively. Codes B, C and D were given to 2x1 cotton polyester elastin, 3x1 cotton elastin and 3x1 cotton polyester elastin samples respectively.

2.4 Evaluation of Fabric Properties

Shrinkage of fabrics was tested by ISO 3759. Physical characteristics of dried fabrics were evaluated according to standard testing procedures. Five response variables were Tensile strength, Stretch, Growth and recovery at constant and cyclic loading, Shrinkage and colour strength (K/S). Tensile strength was evaluated in warp and weft directions as per ASTMD 5035. Stretch, Growth and recovery at constant load was performed in elastin direction (weft) using standard method ASTM D 3107, stretch was checked after 30 minutes and growth at 3 lb load after 60 minutes. Stretch, Growth and recovery at cyclic loading was done in warp and weft directions as per ISO-14704-1, constant load of 30N and 5 cycles were kept for all specimens. Growth was measured after 30 minutes. Colour strength (K/S) was measured using a Data colour Spectroflash 650 spectrophotometer, with a 10° standard observer and D65 illuminate. The Kubelka–Munk equation was used for the measurement of k/S and it is given in Eq. 1.

$$\left(\frac{K}{S}\right)_{\lambda} = \frac{(1-R_{\lambda})^2}{2R_{\lambda}} \quad (1)$$

Where; K is the absorption coefficient, S is the scatter coefficient, R is the reflectance expressed as a fractional value at wavelength of maximum absorption λ [15].

Before testing, all fabrics were conditioned in the laboratory at 65+2% relative humidity and 20+2 °C temperature. Fabric samples were conditioned before and after washing to measure shrinkage. Washed elastin samples were divided into three lots. Each lot contained 25 elastin denim fabric samples. Prepared lots were dried at 50ºC, 60ºC and 70ºC temperatures for 10 minutes. As per ISO 3759 standard, average shrinkage at three different temperatures of Cotton and PC elastin denim fabric samples were evaluated and shown, see Table IV to Table IX. Five replicates were used. Each replica was tested for the number of specimens as mentioned in the standard test procedures.

2.5 Marker Layout and Fabric Consumption

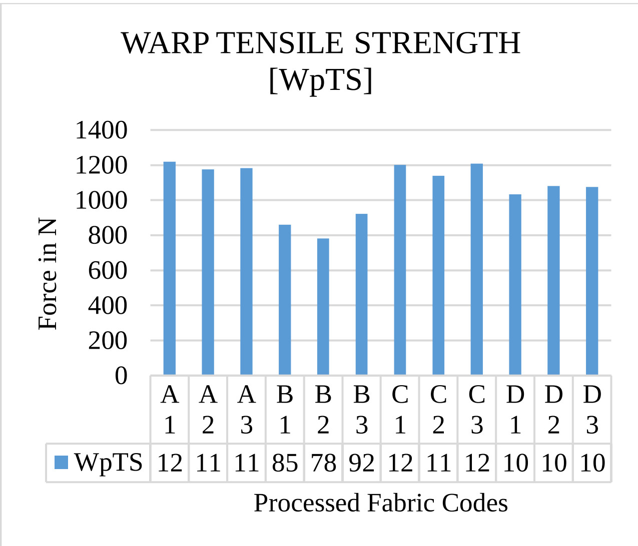
In marker layout, fabric consumption depends on the area of pattern versus the area of the marker by considering the grading points. Grading means number of sizes produced in particular order. In the present research, considers 40, 44, 48 and 52 grading sizes for each 100 trouser pieces at fixed cut-able width (136 cm). Practically in denim industry for optimum marker layout for respective fabric consumption mainly considers width wise fabric shrinkage % as compared to length wise shrinkage in marker making layout to avoid fabric wastage.

3. Results and Discussion

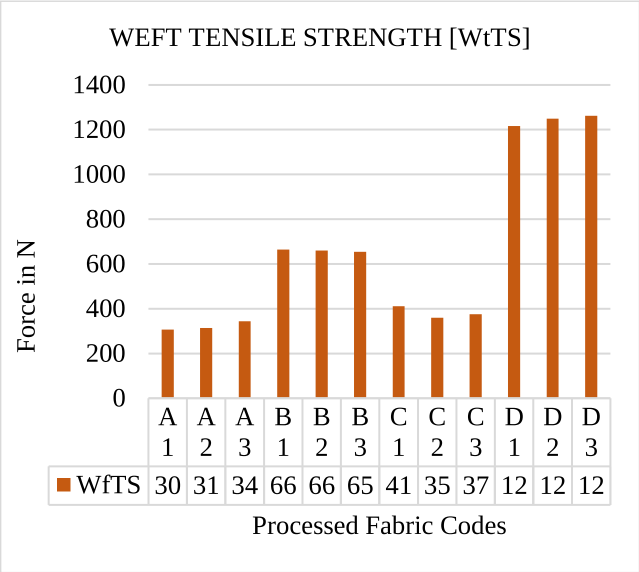
Averages of each response; Tensile strength, Stretch, Growth and recovery at constant and cyclic loading, Colour strength (K/S), Shrinkage (%) and Marker layout are shown in Fig.s 1a to 1b, 2, 3a to 3b, 4, 5a to 5b and 6a- 6d respectively.

3.1 Tensile Strength

Tensile strength of the fabric is the resistance of a material to breaking under tension. Tensile strength testing of denim fabrics was performed after drying at different temperatures. The purpose was to evaluate the effect of drying temperature on the strength and elongation of elastin denim fabrics. The Fig.s 1a and 1b present tensile strength of the denim fabrics in warp and weft directions.



(a)



(b)

Fig. 1. (a) Warp Tensile Strength of Denim Fabrics; (b) Weft Tensile Strength of Denim Fabrics

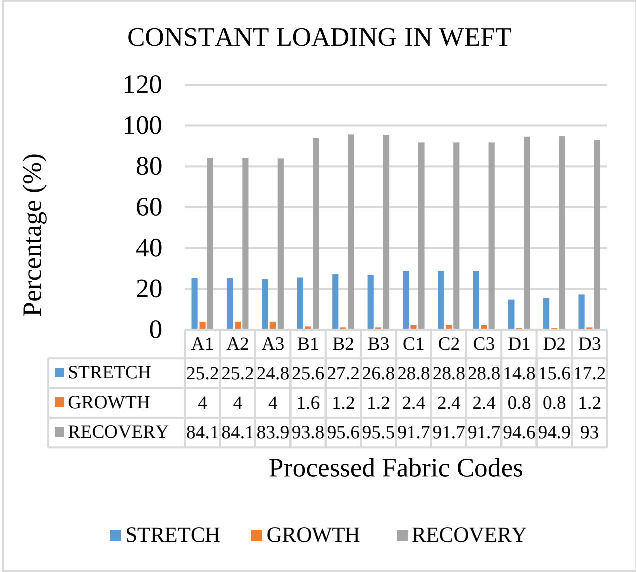


Fig. 2. Weft Stretch, Growth and Recovery of Denim Fabrics at constant loading

It can be observed in Fig. 1a that the tensile strength of denim fabric in warp direction was not significantly affected by varying drying temperature. Strength of Cotton elastin 2/1 twill fabric (shown as A1 to A3) did not change significantly upon varying temperature from 50°C to 70°C. The same trend can be observed for 2x1 cotton-polyester-elastin (B1 to B3) 3x1 twill fabrics (C1 to C3 and D1 to D3). Similarly, tensile strength in weft has the same trend as that in warp direction, see Fig. 1b.

3.2 Stretch, Growth and Recovery at Constant Load

Denim fabrics selected for this study contained elastin (Lycra). Stretch ability is desired for comfort during movements especially for denim jeans. 10–35% elasticity is generally required and it is achieved by varying proportion of elastin in the fabric [16]. A good quality of elastin has high stretch ability with low growth (high recovery). Results of stretch, growth and recovery at constant load (3 lb.) in weft direction are shown in Fig. 2.

It can be seen in Fig. 2 that stretch; growth and recovery of cotton-elastin 2x1 twill weave denim fabrics (A1 to A3) didn’t change by varying drying temperatures selected for this investigation. This trend is somehow similar to the trends shown by 2x1 twill weave cotton Polyester elastin (B1 to B3) and 3x1 twill weave denim fabrics samples (C1 to C3 and D1 to D3).

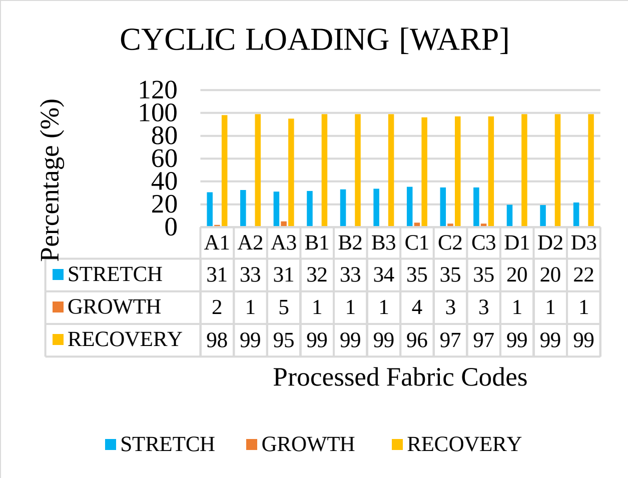
Stretch, growth and recovery values were found different among the selected fabrics for this investigation due to the differences in weave and blend ratios (Table 1).

3.3 Stretch, Growth and Recovery at Cyclic Loading

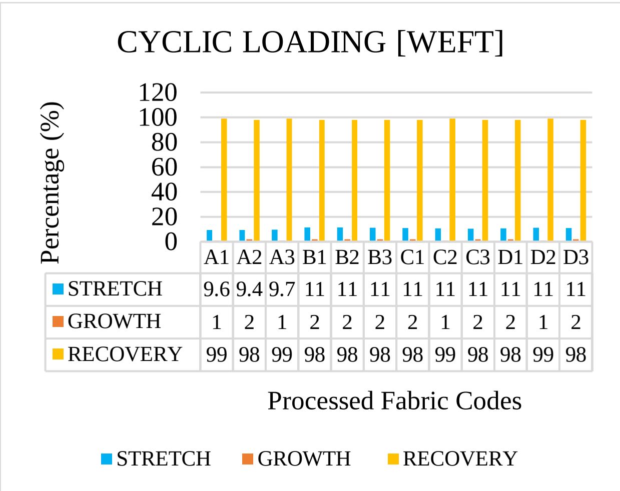
To make casual wear comfortable, elastin denim fabrics are always in demand [17]. Denim fabrics are subjected to stresses due to the body movements. It may be indirectly affected by the dynamic elastic recovery value of the fabrics. Cyclic loads lead to the redistribution of fibres in the yarn structure, because they tend to get the minimum level of energy to remain stable [18].

Body movement causes recurring loading and unloading of garments so Stretch, Growth and recovery (during cyclic loading) test was also performed in this study at 30 N and 5 cycles.

Fig.s 3a and 3b depicted Stretch, growth and recovery of 2x1 and 3x1 twill denim fabrics in warp and weft directions respectively.



(a)



(b)

Fig. 3. (a) Warp Stretch, Growth and Recovery of denim elastin fabrics at cyclic loading; (b) Weft Stretch, Growth and Recovery of denim elastin fabrics at cyclic loading

Slight change in values of stretch, growth and recovery values of cotton-elastin, 2x1 twill denim fabric (A1 to A3) in warp direction was observed upon varying drying temperatures, see Fig. 3a. The same trend is found for the remaining samples either (B1to B3, C1 to C3 and D1 to D3). Fig. 3b displayed the same trends of stretch, growth and recovery among all samples, in weft direction too.

However, stretch and recovery values of all the samples are significant with reference to the construction of good quality garments.

3.4 Color Strength (K/S)

Colour strength (K/S) values of dyed denim fabrics were determined using spectrophotometer. K/S (Absorption coefficient (K) and Scattering coefficient (S) were used to measure the depth of colour of dyed fabric. K/S value is used for textile materials to control the process parameters in dyeing and finishing (washing) [19]. Acceptability of a dyed sample against standard, also dependent on its K/S value [15]. K/S values of 2x1 and 3x1 twill denim fabric are shown in Fig. 4.

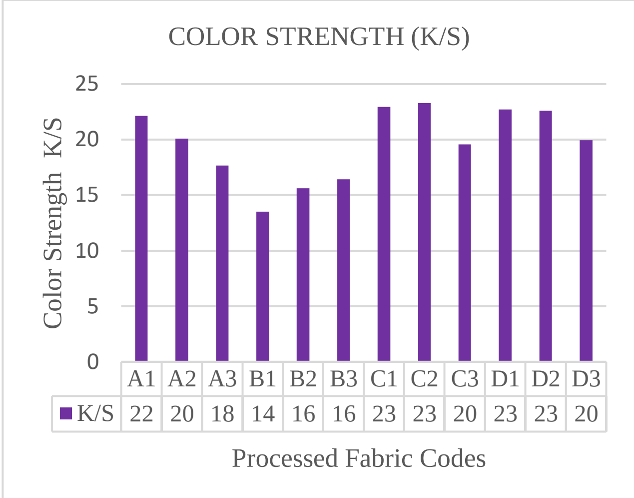
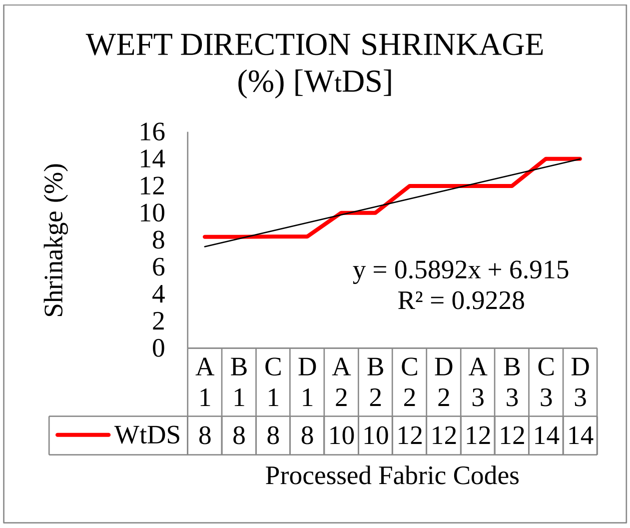


Fig. 4. Color strength (K/S) of denim elastin fabric

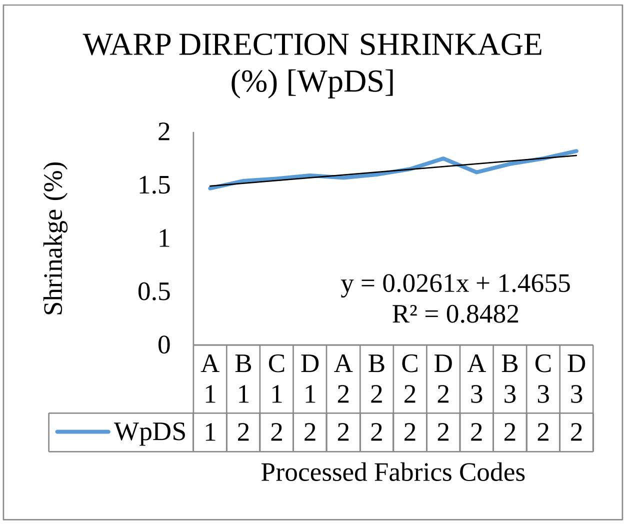
Changed of drying temperature did not significantly affect K/S values of selected denim fabrics. However, there was a decrease in K/S value of cotton elastin, 2x1 twill fabric among samples dried at 50°C, 60°C and 70°C (A1 to A3). Similar trend can be observed for 3x1 twill denim fabrics (C1 to C3 and D1 and D3). However, the trend of 2x1 cotton-polyester-elastin (B1 to B3) was changed i.e. K/S value increased for the sample processed at 70°C compared to the samples dried at 50°C and 60°C because of polyester fibres composition and compacted interlacement of 2X1 weave than 3X1 weave[20]. Each sample had different K/S value because of the difference in their weaves and blend ratios.

3.5 Shrinkage

As per experimental model III, it was observed in Fig. 5 (a) and (b) that shrinkage of 2x1 and 3x1 elastin fabrics shown increasing trend in weft direction from 8% to 14 % however shrinkage in warp direction less than 2% respectively against 50ºC, 60ºC and 70ºC drying temperatures.



(a)



(b)

Fig. 5. (a) Weft direction shrinkage (%), (b) Warp direction shrinkage (%)

There was a significant change in weft direction shrinkage of 2X1 and 3X1 elastin denim fabrics, upon varying dryer temperature from 50ºC, 60ºC and 70ºC owing to the fact that the elastomeric polymer (elastin) consists of rigid and soft segments. It was also observed that weave type and drying temperature significantly impact on shrinkage % from 50ºC to 70ºC on both directions. As shown in Fig. 5a, 2X1 warp faced elastin denim fabric shrinkage increased in weft direction from 8% to 10% (A1 to A2; B1 to B2) and 10% to 12% (A2 to A3; B2 to B3) at 60ºC and 70ºC drying temperature respectively. In contrast 3X1 warp faced elastin denim fabric also shown increase in shrinkage in weft direction from 8% to 12% (C1 to C2; D1 to D2) and 12% to 14% (C2 to C3; D2 to D3) at 60ºC and 70ºC drying temperature respectively. In present research findings, it is found that heating of elastomeric material above 50 ºC caused the development of sufficient kinetic energy to rupture the covalent cross link of the polymer system which as a result adversely altered elastomeric materials properties. It means that the lowest value of shrinkage % was found for 2x1 (A1 and B1) and 3x1 warp faced (C1 and D1) elastin denim; 8% weft direction and less than 2% warp direction at 50ºC dryer temperature because insufficient kinetic energy unable to rupture the covalent cross link of the polymer chain. More shrinkage of elastin denim fabric increased its consumption for particular garment article in marker making to make number of pieces as per required order quantities.

3.6 Marker Layout and Fabric Consumption

Shrinkage data obtained experimentally for selected elastin denim fabric was used to develop Trouser marker layout of 100 pieces of each 40, 44, 48 and 52 grading sizes at fixed cut-able width (136 cm) for a particular trouser style through marker making software called Gerber [21]. Gerber marker making software was used to estimate the elastin denim fabric consumption per piece. Gerber software technique was exercised to arrange the trouser pattern pieces as per mentioned grading sizes for the development of an efficient marker lay out for further processing. Gerber software executed the efficient trouser marker layout on evaluated shrinkage % of 2x1 and 3x1 warp faced denim elastin fabric which is shown in Fig. 6a to 6d [22].

Fig. 6.a Trouser marker layout at 2% warp and 8 % weft direction shrinkage

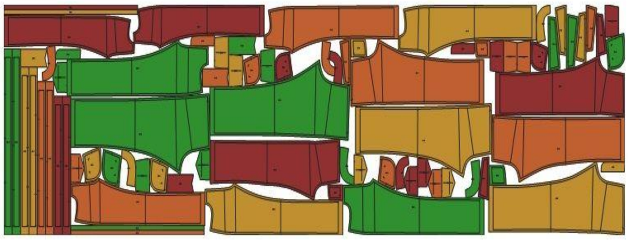


Fig. 6.b Trouser marker layout at 2% warp and 10% weft direction shrinkage

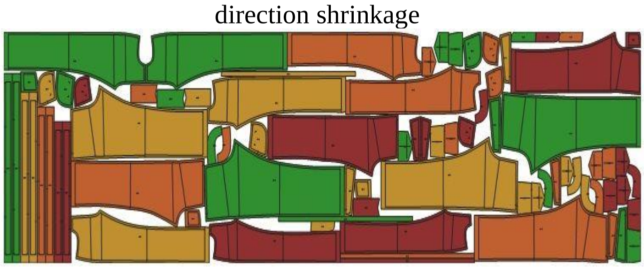


Fig. 6.c Trouser marker layout at 2% warp and 12 % weft direction shrinkage

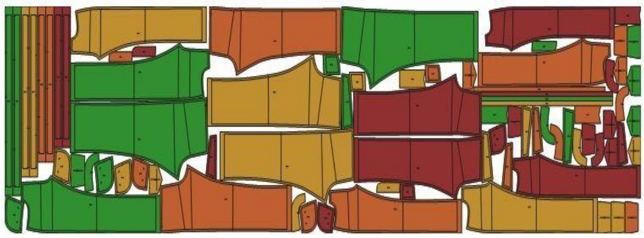


Fig. 6.d Trouser marker layout at 2% warp and 14 % weft direction shrinkage

It can be seen in Table X that the difference of elastin denim fabric consumption at 136 cm fixed cut table width for 400 pieces trousers varied with fabric shrinkage (%) depended on the dryer temperatures. Higher dryer temperature increases shrinkage of stretchable denim fabric.

Table I

Garber software marking making parameters at different shrinkage %

Parameters	Shrinkage (L*W) %			
	2x8	2x10	2x12	2x14
Cutting Width (cm)	136.00	136.00	136.00	136.00
Length of spread, 400 pieces (cm)	488.05	495.78	560.73	515.43
Consumption per piece (meters)	1.25	1.27	1.30	1.32

It is established that elastin denim fabric consumption also seems to depend upon denim fabric weave type at constant pattern along with grading points. By increasing drying temperatures, stretchable denim fabric consumption augmented at fixed cut table width for same number of pieces production which is shown in Table X through following Eq.s:

$$Elastin\ fabric\ consumption\ at\ 70\ C\ dryer\ temperature\ \text{per}\ trouser\ piece\ = 1.32 meter \quad (2)$$

$$Elastin\ fabric\ consumption\ at\ 60\ C\ dryer\ temperature\ \text{per}\ trouser\ piece\ = 1.3 meter \quad (3)$$

$$Elastin\ fabric\ consumption\ at\ 50\ C\ dryer\ temperature\ \text{per}\ trouser\ piece\ = 1.25 meter \quad (4)$$

$$difference\ of\ elastin\ fabric\ consumption\ between\ 70-50\ C\ per\ trouser\ piece\ = 0.07\ meter \quad (5)$$

In this experimental investigation, shrinkage of fabric after drying it at 70ºC, caused consumption of 28 meter (0.07*400) more denim than those samples dried at 50ºC and 60ºC to make 400 pieces of trouser.

Fig. 6e reflects a significant coefficient of determination (R^2= 0.9931) between fabric consumption per piece and different fabric shrinkage (weft) at 2% constant warp direction shrinkage.

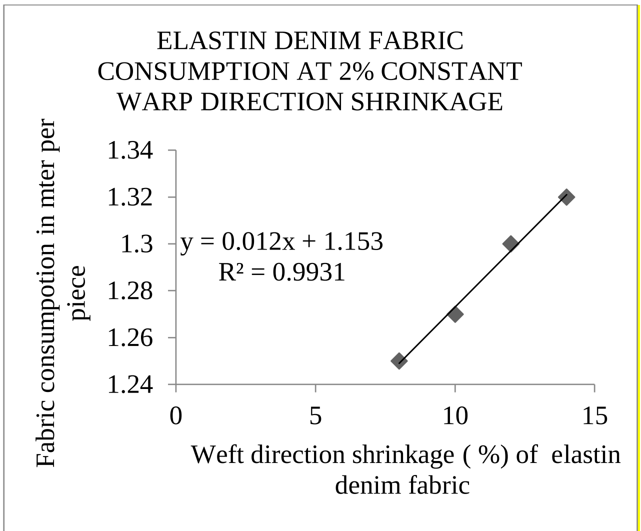


Fig. 6.e Relation between fabric consumption (meter) and weft direction fabric shrinkage %

It is proposed that elastin denim fabrics can be washed and dried at 50ºC to avoid fabric wastage and hence reduce consumption in marker making layout to develop a particular style. It is also found that shrinkage of cotton and cotton-polyester elastic denim in weft direction has significant impact marker making at fixed cut-able width (136cm) for a particular garment. These experimental findings provide the guideline to the denim manufacturing industries to avoid wastage of fabric, energy, money and utilities cost.

4. Conclusion

The present research suggests denim manufacturing industries to dry stretchable/elastin denim at 50ºC drying temperature for 10 minutes (after washing) to avoid unnecessary shrinkage. It will reduce elastin denim fabric consumption without compromising on Tensile strength, Stretch (growth and recovery at constant and cyclic loading) and colour strength (K/S) of required shade. Results show excellent stretch and recovery values of all samples at 50ºC drying temperature. Estimated shrinkage % of elastin denim fabric has significant coefficient of correlation (R^2= 0.9931) with fabric consumption per piece. The proposed investigation is an attempt to lessen usage of resources to process elastin denim fabric with main emphasis on minimizing elastin denim fabric consumption. Outcomes of this research will help denim industries to revise processing parameters to save energy, water, chemicals and elastin denim fabric. It will also aid in cutting the costs involved in elastin denim processing. This study is an effort of providing sustainable solution to process elastin denim fabrics.

5. Competing interest

No conflict of interest.

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