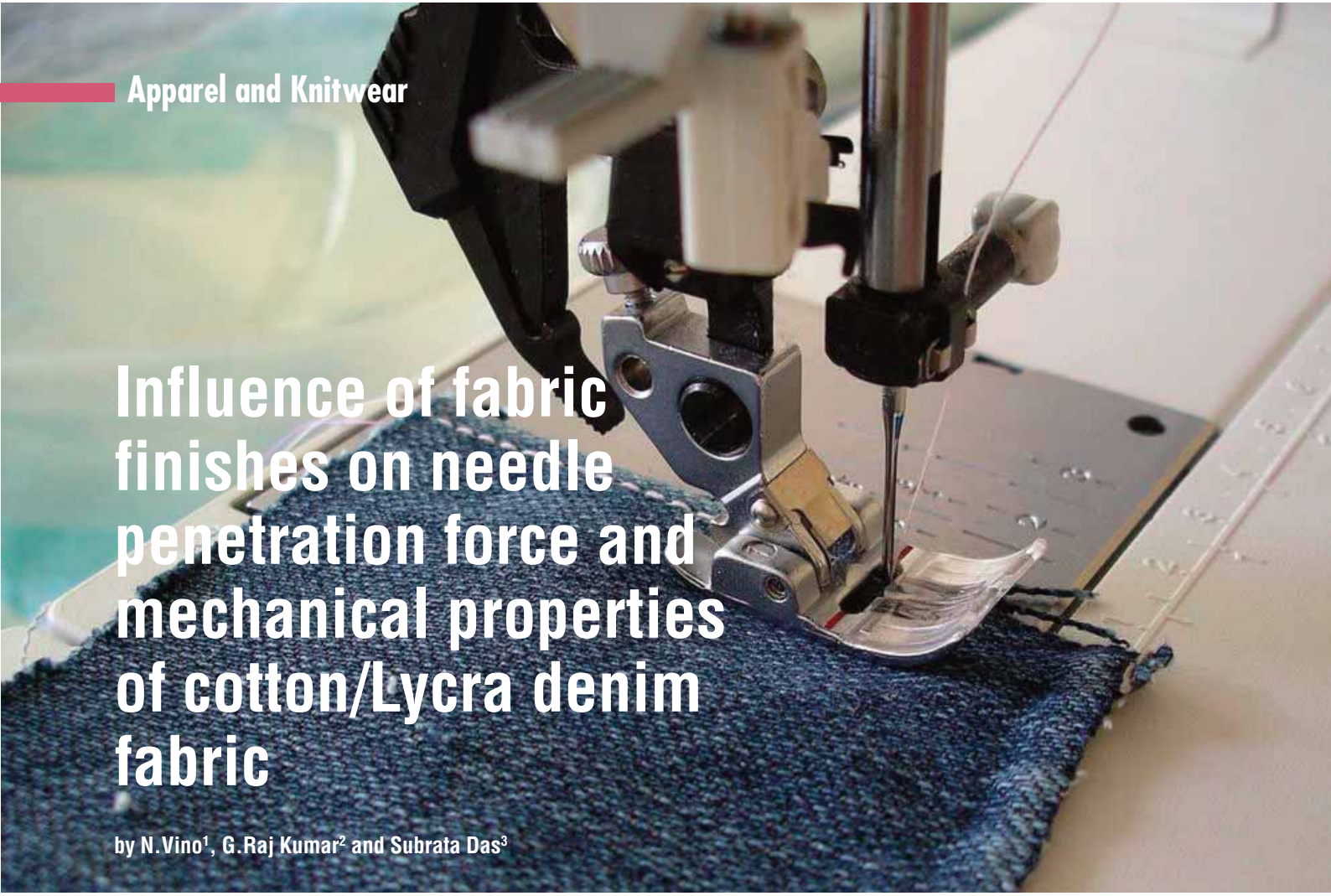

Influence of fabric finishes on needle penetration force and mechanical properties of cotton/Lycra denim fabric

by N.Vino[1], G.Raj Kumar[2] and Subrata Das[3]

Influence of fabric finishes (pigment, enzyme and stone wash) on the seam quality of cotton/Lycra denim fabric is investigated in this study. The quality of seam is determined by measuring needle penetration force, needle cutting index and seam mechanical properties. Three different needle sizes (14,16 and18 Nm) are used to study the needle penetration force of different finished cotton/Lycra denim fabric. The number of fabric layers from 1 to 4 is used for three different needle sizes. Better sewability is noticed for unfinished and finished cotton/Lycra denim fabric sewn by needle size 14 and 16, respectively in comparison to other needle sizes. Needle cutting index and seam mechanical properties of cotton/Lycra denim fabric with different finishes are also been studied.

Keywords: Sewability, needle penetration force, needle cutting index, sewing thread tension

1. Introduction

The garment industry is one of the main economic sectors, which has an important role in everyday life and global economics[1]. Among woven fabrics the usage of denim, as a main part of garment fashion, is greatly increasing every year[2,3]. In the garment manufacturing sector, pressure on garment manufacturers has increased due to competition in global markets for providing best quality and economic price of apparels[4]. The quality of garments depends on quality of fabric and accessories, sewing condition, and fabric sewability. Sewability of a fabric is an important factor which decides the quality of seam and which is influenced by many factors such as properties of sewing threads and fabrics, processes of needle penetration force, stitch formation, sewing thread tension, fabric feeding, seam construction and various technological parameters in sewing process. Sewability can be defined as ease of formation of shell structures and the ability of material to be seamed effectively without fabric damage, and also to provide suitable end-use performance[5, 6]. The problems related to sewability are not restricted to a particular section of the sewing industry; but is widely considered in the whole of the apparel manufacturing processes. The study of sewability can help better understanding of the interaction between one or more plies of fabric, which are sewn with sewing thread[7, 8]. In addition to seam efficiency, puckering, slippage, damage and appearance, the needle penetration force (NPF) and needle cutting index are other factors which is used to determine fabric sewability. According to newly developed processes in garment manufacturing, particularly in the denim garment, the study of denim sewability in clothing manufacture is important. In the sewing process, a fabric with a high density, thickness, and weight such as denim fabric is more prone to

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damage[5]. At the same time, if the sewing needle is not correctly selected with respect to the fabric construction, the sewability of fabric becomes poor in the final product. The market share of denim has increased several folds in the last few decades. In denim garments, sewing threads possess a linear projection on the surface and are subjected to abrasion. Therefore, unless the sewing thread is strong enough, it may break during sewing of denim[9]. At present, mainly three types of sewing threads such as spun polyester thread, cotton wrapped poly-core thread and poly-wrapped poly-core thread are used in sewing of denim garments. The integration of various parameters related to sewing thread, fabric and sewing machine settings at their optimum level results in good sewability. The sewability of various types of fabrics has been studied by several researchers. The quality and performance of a sewn garment depends on various factors such as seam strength, seam slippage, seam pucker and yarn severance[10]. In sewn garments, sewing damage is a constantly recurring phenomenon and is the major cause of customer complaint.

The present study aims at investigating the influence of fabric finishes on seam quality of cotton/Lycra denim fabrics, to analyse the effect of needle size on needle penetration force and needle cutting index on cotton/Lycra denim fabrics and to study the mechanical properties of the cotton/Lycra denim fabrics.

2 Materials and Methods

2.1 Materials

2.1.1 Selection of denim fabric

Cotton/Lycra denim fabric was procured from the KG Denim, Karamadai, India is used in this study.

2.1.2 Physical characteristics of denim fabric

The physical characteristics of denim fabric such as fabric weight and yarn count were measured according to ASTM Standards D 3776 and D3775, respectively. The EPI, PPI and thickness were also analysed by means of ASTM Standards D 3775 and D 1777. Statistics regarding physical characteristics of denim fabric are given in **Table 1**.

Table 1: Physical characteristics of denim fabric

S. No.	Fabric Code	Weave Type	Yarn Count (Tex)		Weight (g/m²)	Thickness (mm)	Ends per inch	Picks per inch	Cloth Cover factor
			Warp	Weft					
1	D1	T 3/1	20	21	370	0.66	26	24	12
2	D2	T 3/1	18	20	450	0.75	29	27	13
3	D3	T 3/1	22	19	477	0.88	31	28	13
4	D4	T 3/1	19	21	469	0.81	32	31	15

Fabric codes: D1-Cotton/Lycra denim fabric, **D2**-Pigment finished Cotton/Lycra denim fabric, **D3**-Enzyme finished Cotton/Lycra denim fabric and **D4**-Stone washed Cotton/Lycra denim fabric.

Scheme 1: Process of stone wash finishing method

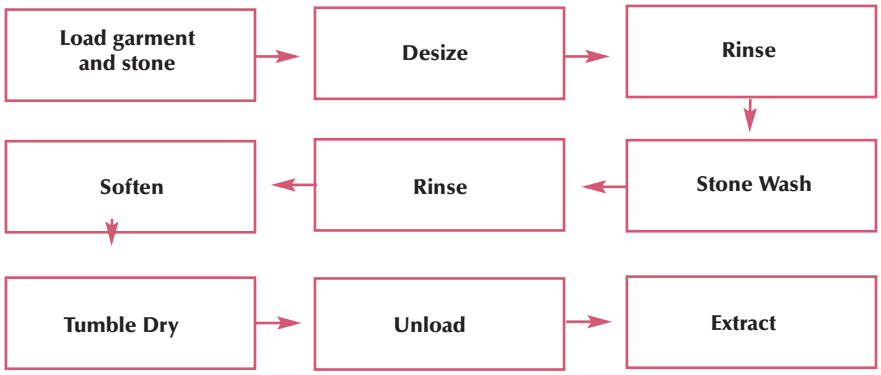

Table 2: Condition for Stone Wash Finishing Method

Details	Quantity
M:L	1:8
Temperature	50-70 °C
Time	30-90 min
Drying	Tumble drying

Scheme 2: Process of enzyme finish denim fabric

Table 3: Condition for Enzyme Finish Denim Fabric

Details	Quantity
M:L	1:15
Temperature	70 ° C
Time	30-90 min
Drying	Tumble drying

2.2.2 Enzyme Finished Denim Fabric

It is environmentally friendly wash and involves the application of organic enzymes that eat away fibres in the fabric, i.e. the cellulose. When the desired color is achieved, the enzyme activity can be terminated by changing the alkalinity of the bath or its temperature. Post treatment includes final rinsing and softening cycle. Process flow chart and condition of enzyme finish denim fabric is given in **Scheme 2** and **Table 2**, respectively.

2.2.3 Pigment Dyeing Method

Pigment dyeing is not really "dyeing" in its truest form because the pigments stick on the fabric with the help of binders. Pigments are insoluble in water. They exist in the form of finely ground molecules, milled for garment dyeing purposes into a paste. When anionic dispersing agents are added, a slightly negative charge is present, thus the foundation for pigment dyeing is born. When a positively charged cationic pre-treat is added to the fiber a magnetic bond is formed. The process is complete when a cationic binder is added to "lock" the pigment into place. In pigment dyeing no actual chemical reaction takes place between the dye and the fabric. Process flow chart and condition of enzyme finish denim fabric is given in **Scheme 3** and **Table 4**, respectively.

2.2.4 Evaluation

2.2.4.1 Needle Penetration Force (Cotton/Lycra Denim Fabric)

In order to determine the Needle Penetration Force (NPF), at first the maximum needle penetration force in each cycle was defined. Then the average of these values in 25 cycles was taken into account as NPF for each case. In this study for calculating sewability values (i.e needle penetration force) different number of layers has been taken. In order to calculate the needle penetration force three different needle sizes were taken (80/14,100/16,120/18) and different fabric layers ranges from 1 to 4 were taken and the sewability value were analysed. Photomicrograph of a typical Needle Penetration Force Tester is given in **Figure 1**.

Table 4: Condition of Pigment Dyeing Method

Details	Quantity
M:L	1:20
Binder	10 g/l
Temperature	70 °C
Time	20 min
Drying	Tumble drying

Scheme 3: Process of pigment dyeing method

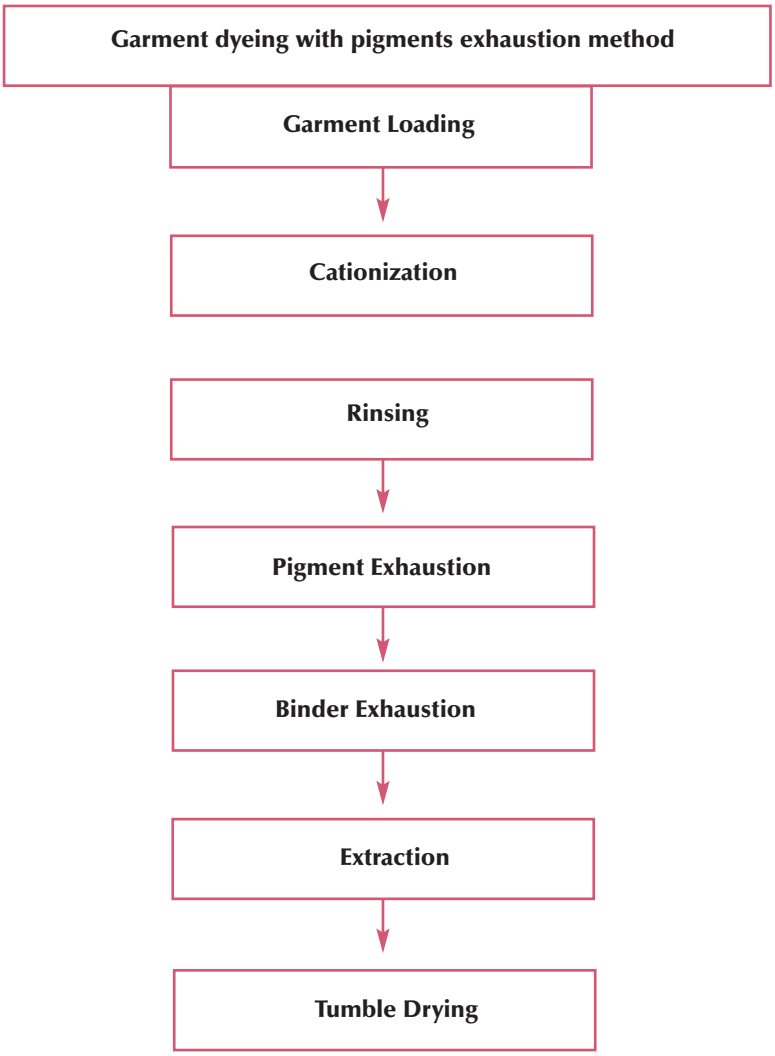

Fig. 1: Needle Penetration Force Tester.

2.2.4.2 Fabric Thickness and Fabric Weight (GSM)

Thickness is the perpendicular distance between two reference plates exerting a load of 20 gm/cm2, and is measured using a thickness gauge and following the method IS 7702: 1975 (34-35) and ASTM D 1777: 1996.

Grams per Square Meter (GSM) of the fabric are measured at five different places by following ASTM D 3776: 1996 and the average value is reported.

2.2.4.3 Fabric Tensile Strength

Fabric tensile strength of woven apparel fabrics was measured by following ASTM D5035.

2.2.4.4 Seam Puckering

Test Method AATCC- 88B:2011 is designed to evaluate the seam appearance in fabrics after repeated home laundering. Any washable fabric may be evaluated for seam appearance using this method. Fabrics of any construction, such as woven, knit and

nonwoven may be evaluated according to this method. Techniques for seam appearance are not outlined, since the purpose is to evaluate fabrics as they will be supplied from manufacturing or as ready for use. Furthermore, seam appearance techniques would be controlled by fabric properties.

2.2.4.5 Seam Efficiency Index

Seam efficiency is measured according to ASTM-D 1683 method on the Instron tensile tester. Seam efficiency was calculated as the percent seam strength over fabric strength by using the following formula:

Seam tensile strength fabric tensile strength X 100

2.2.4.6 Needle Cutting Index

Needle cutting in a fabric is objectionable because it may result in reduced seam strength or poor appearance or both due to frayed yarns. Under the ASTM-D 1908 test method on Mitsubishi Micro Watcher for needle cutting, sewn seams are prepared for testing unless seams are taken from previously sewn articles. The sewing threads are removed from the test specimens. The count of the number of fabric yarns and the count of the number of severed and fused fabric yarns in the direction most nearly perpendicular to the direction of sewing are used to calculate the needle cutting index. For each sample, needle-cutting index was determined using the following formula:

Number of yarns cut/inch number of yarns in fabric/inch X 100

3. Results and Discussion

3.1 Needle Penetration Force (Cotton/Lycra Denim Fabric)

From **Table 5** and **Figure 2**, it is observed that the needle size 80/14 shows good sewability value for the first two fabric layer for the cotton/Lycra denim fabric (light weight) when compared to other needle sizes. The NPF becomes poor for the fabric layer three and four where the weight of the fabric increases which leads to tear the fabric.

3.2 Fabric Thickness and Fabric Weight (GSM)

The test result for the fabric thickness and fabric weight are listed in **Table 6**. It is evident that the weight and thickness of the fabrics (D2, D3 and D4) increased due to the special finishing method when compared to the normal cotton/Lycra denim fabric (without finishing – D1).

Table 5: Needle Penetration Force (Nm) for Cotton/Lycra Denim Fabric

S. No.	Needle Size	No of fabric layers(NPF)							
		1		2		3		4	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	80/14	10	09	12	08	100	96	100	100
2	100/16	32	25	39	67	100	100	92	100
3	120/18	23	21	11	54	100	100	100	100

Fig. 2: Needle Penetration Force for Cotton/Lycra Denim Fabric

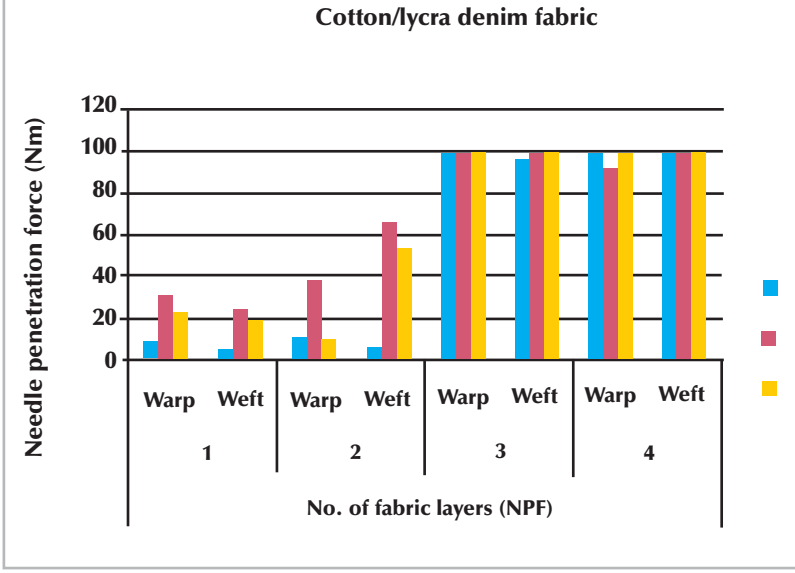

Table 6: Fabric Thickness And Fabric Weight

S. No.	Fabric Code	Weight (g/m²)	Thickness (mm)
1	D1	370	0.66
2	D2	450	0.75
3	D3	477	0.88
4	D4	469	0.81

3.3 Fabric Tensile Strength

The strength of fabric has been determined by tensile strength tester. The results are shown in the **Table 7** and **Figure 3** on the next page. The fabric strength increases in proportion to the finished denim fabric.

Finished denim fabrics (pigment, enzyme, stone wash finish) have higher strength and elongation when compared to unfinished cotton/Lycra denim fabric. All finished fabric samples show higher strength due to its increase in weight.

The sewability analyser was used to get the values of needle penetration force, shown in **Figure 4**. In this graph "total" indicates the number of needle penetration and the "high" indicates the NPF values. The threshold value will change frequently where it depends upon the fabric weight (i.e) fabric weight is directly proportional to the threshold value. The speed and the range are

constant. Here the NPF value is 009 which show that the sewability is good for the light weight denim fabric.

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3.4 Needle Penetration Force (Pigment Finished Denim Fabric)

The needle penetration force for the pigment finished denim fabric is shown in the **Table 8** and **Figure 5**. The needle size 100/16 shows superior sewability for the pigment finished denim fabric when compared to other needle sizes. The sewability analyser shows the NPF value of 16 in the weft direction which shows sewability value is satisfactory. From the graph it is clear that the NPF value is good for the first two layers of pigment finished denim fabric.

3.5 Needle Penetration Force (Enzyme Finished Denim Fabric)

The needle penetration force for the enzyme finished denim fabric is shown in **Table 9** and **Figure 6**. The needle size 100/16 shows superior sewability for the enzyme finished denim fabric when compared to other needle sizes. The sewability analyser shows the NPF value of 23 which shows sewability value is satisfactory. From the graph it is clear that the NPF value is good for the first two layers of enzyme finished denim fabric.

3.6 Needle Penetration Force (Stone Wash Finished Denim Fabric)

The needle penetration force for the stone wash finished denim fabric is shown in **Table 10** and **Figure 7**. The needle size 100/16 in the weft direction shows superior sewability for the stone wash finished denim fabric when compared to other needle sizes. The sewability analyser shows the NPF value of 11 which shows sewability value is good. From the graph it is clear that the NPF value is good for the first two layers of stone wash finished denim fabric.

Table 7: Fabric Tensile Strength

S. No.	Fabric Code	Weight (g/m²)	Thickness (mm)
1	D1	370	0.66
2	D2	450	0.75
3	D3	477	0.88
4	D4	469	0.81

Fig. 3: Fabric Tensile Strength

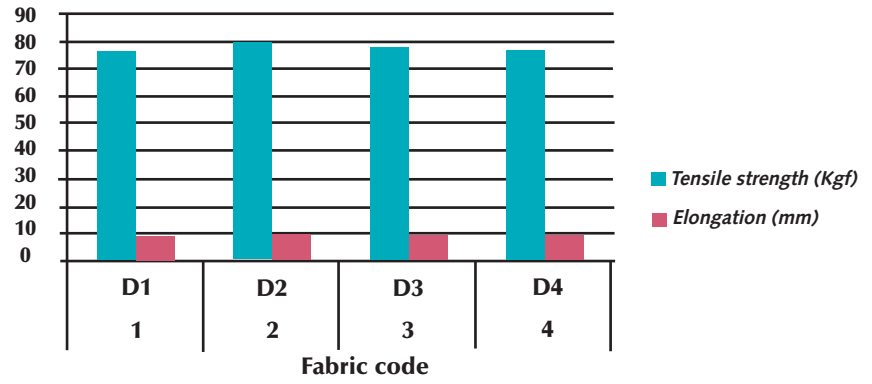

Fig.4: Needle Penetration Force (Cotton / Lycra Denim Fabric)

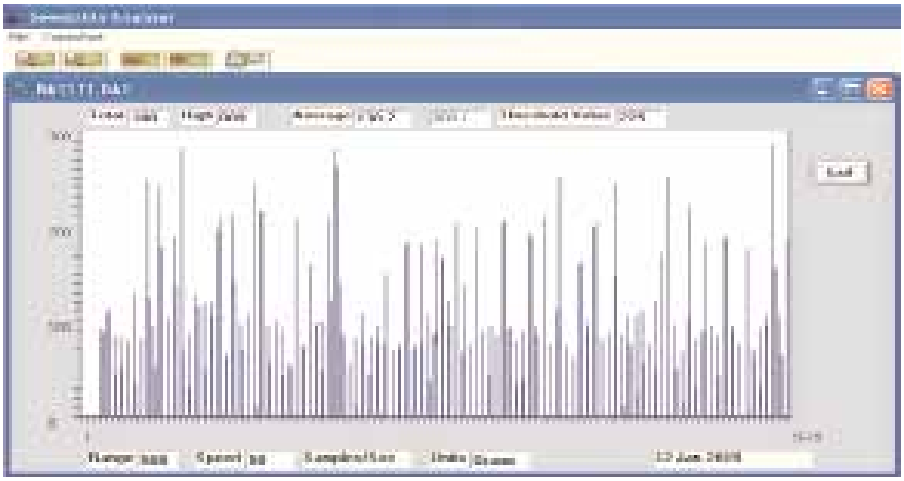

Table 8: Needle Penetration Force (Nm) for Pigment Finished Denim Fabric

S. No.	Needle Size	No. of fabric layers (NPF)							
		1		2		3		4	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	80/14	50	42	57	81	100	100	100	100
2	100/16	09	16	01	24	100	97	97	100
3	120/18	24	33	32	56	100	92	100	100

The seam pucker grade for the double seam with SPI-12 for the cotton/lycra denim fabric is found to be superior when compared to other special finished denim fabric. From **Table 11** it is observed that

there is significant reduction in seam pucker which might due to higher tenacity at break in weft direction and the tension in needle thread is less in weft direction. This could be the reason for less pucker in weft direction as compared with warp direction.

The seam pucker grade for the single seam with SPI-12 for the cotton/lycra denim fabric is found to be superior when compared to other special finished denim fabric. From **table 4** it is clear there is significant reduction in seam pucker which might due to higher tenacity at break in weft direction and the tension in needle thread is less in weft direction. This could be the reason for less pucker in weft direction as compared with warp direction.

From the **Table 13** and **Figure 8**, it is found that the seam efficiency index is superior for both finished and unfinished denim fabric.

3.9 Needle Cutting Index

The needle cutting index of the samples is shown in the **Table 14** and **Figure 9**. It is observed that the unfinished denim fabric shows higher needle cutting index when compared to the especially finished denim fabric.

4. Conclusions

4.1 It can be concluded that this research shows that the needle size 80/14 is well suited for the normal cotton/lycra denim fabric (without finishing) when compared to other needle sizes.

4.2 The needle size 100/16 is well suited for the specially finished denim fabric (pigment, stone and enzyme finishes) when compared to other needle sizes.

4.3 Increase in weight and thickness are observed in all cases of fabrics after special finishing was given.

4.4 The seam pucker was better for the light weight cotton/lycra denim fabric when compared to the special finished denim fabric.

4.5 Seam efficiency measures the durability along the seam line. Results show that the seam efficiency was superior for both finished and unfinished denim fabric.

4.6 The needle cutting index was better for the unfinished denim fabric when compared to specially finished denim fabric.

Fig.5: Needle Penetration Force For Pigment Finished Denim Fabric

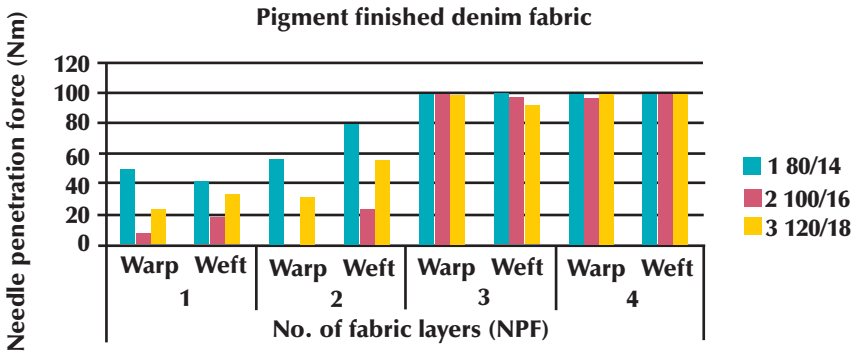

Table 9: Needle Penetration Force (Nm) for Enzyme Finished Denim Fabric

S. No.	Needle Size	No. of fabric layers (NPF)							
		1		2		3		4	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	80/14	35	35	54	69	100	100	92	100
2	100/16	13	15	17	20	100	86	91	100
3	120/18	27	29	25	30	96	100	100	100

Fig.6: Needle Penetration Force For Enzyme Finished Denim Fabric

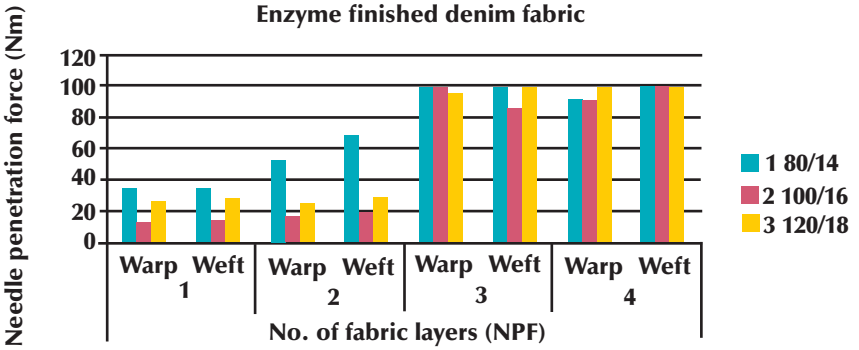

Table 10: Needle Penetration Force (Nm) for Stone Wash Finished Denim Fabric

S. No.	Needle Size	No. of fabric layers (NPF)							
		1		2		3		4	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	80/14	26	29	22	27	100	100	100	100
2	100/16	12	16	09	07	96	100	98	100
3	120/18	25	27	15	57	100	100	100	100

Fig.7-Needle Penetration Force for Stone Wash Finished Denim Fabric

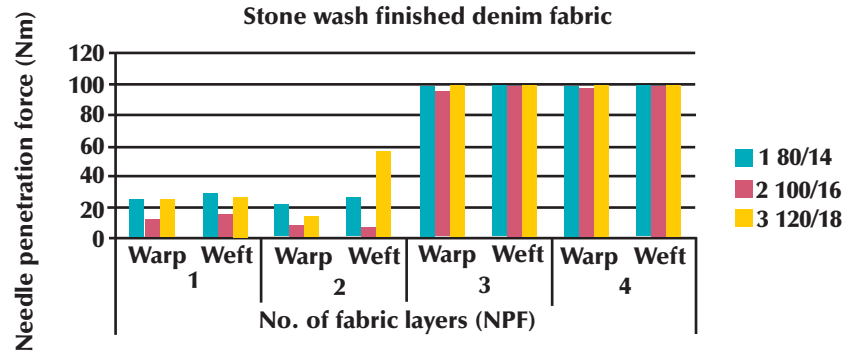

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Table 11: Seam pucker grade for double seam
Seam pucker grade for double seam with SPI-12

S. No.	Fabric code	Warp direction		Weft direction	
		Entropy values	Grade	Entropy values	Grade
1	D1	4.9	Class 5	4.3	Class 5
2	D2	5.0	Class 4	4.4	Class 4
3	D3	5.4	Class 3	4.9	Class 4
4	D4	5.4	Class 3	5.2	Class 3

Table 12: Seam pucker grade for double seam
Seam pucker grade for single seam with SPI-12

S. No.	Fabric code	Warp direction		Weft direction	
		Entropy values	Grade	Entropy values	Grade
1	D1	4.9	Class 5	4.7	Class 5
2	D2	5.4	Class 3	4.9	Class 5
3	D3	5.9	Class 2	4.2	Class 4
4	D4	5.0	Class 4	4.5	Class 4

Table 13: Seam Efficiency Index

S.No	Fabric code	Seam efficiency index (%)
1	D1	54.6
2	D2	48.4
3	D3	52.3
4	D4	50.9

Table 14: Needle Cutting Index

S.No	Fabric code	Needle cutting index (%)
1	D1	7.45
2	D2	6.93
3	D3	5.29
4	D4	5.18

Fig. 8: Seam efficiency index (%)

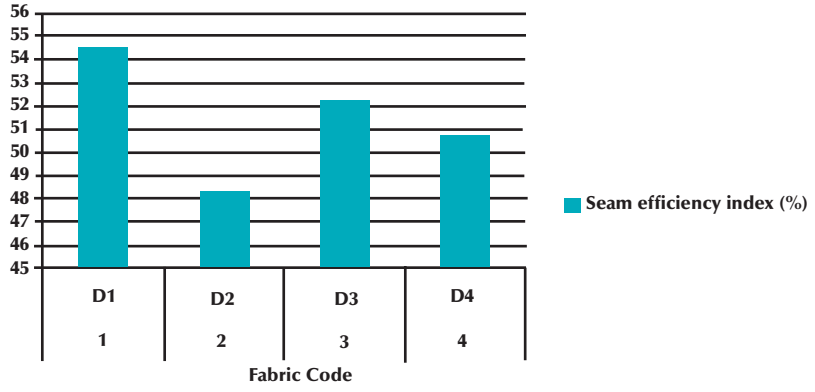

Fig. 9: Needle cutting index (%)