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FABRICATION OF KNIT AND WOVEN DENIM FABRIC AND ANALYSIS OF COST AND END USE PROPERTIES

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Abstract: The knitted and woven denim fabric is manufactured in the world. The suitability of knitted denim for formal wear is poor. Casual wear usage of knitted denim is good. The suitability of knitted denim to wear as formal dress is attempted. The knitted denim is tested for its bending, crease recovery, drape and washing treatments. The drape and washing treatment property for knitted denim is good. Bending and crease recovery property is poor. This is because of the loop structure of the fabric. The bending and crease recovery property can be improved through introduction of spandex or elastocene or lycra yarn in the fabric.

Index Terms; Knit denim, knit loops, woven denim, bending, crease recovery, drape, washing

1. Introduction

The global denim jeans market was forecast to be worth around 87.4 billion U.S. dollars by 2027, up from 63.5 billion U.S. dollars in 2020. The denim jeans market is a sub-category within the overall apparel market. As the global apparel market grows, it is unsurprising that the denim jeans market will also rise. These are given in reference (1).

Denim is the fastest recovering market segment post the pandemic outbreak and according to a recent projection by Research and Markets, a leading market research agency, the global market for jeans valued at US $63.5 Billion in 2020 and will see a revised size of US$87.4 billion by 2027, growing at a CAGR of 4.7 per cent over the period 2020-2027.India has been a leader in denim fabrics and off late the domestic jeans market has also been growing steadily, in fact faster than the global growth rate; various market studies suggest that the Indian domestic market for denim has been maintaining an average CAGR of 8 to 9 per cent for few years and is expected to reach Rs. 91,894 crore (US $ 12.27 billion) by 2028. These are given in reference (2).

What is denim ?

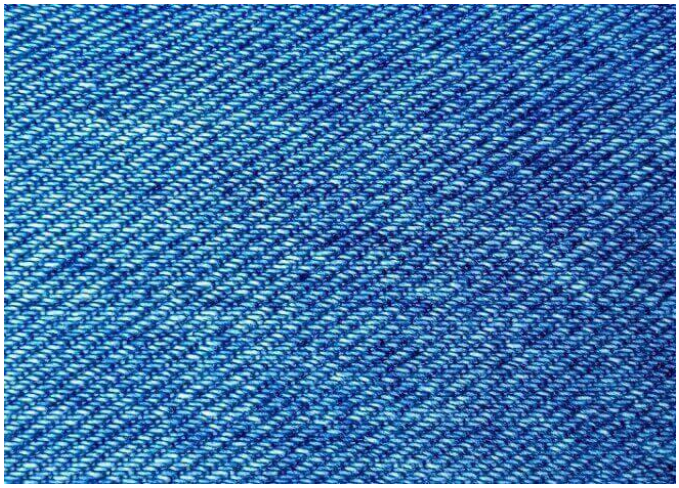
If you came here looking for different types of jeans check out this post. If you are looking for info on denim, the fabric, you are in the right place.

Denim is a rugged, sturdy, twill weave woven, 100% cotton fabric.

The word ‘Denim’ is derived from a french word *Serge de Nimes* and refers to the city of Nimes; De Nimes means ‘of the Nimes’. We have embraced denim into our daily lives like no other.

Denim is made from cotton fibers.

The weave that creates Denim



Denim fabric usually has a twill fabric weave. And this itself makes it a very strong fabric. Do you know that it was used as sailcloth once upon a time? That is how hardwearing it is. Denim is also available in plain weave but it is mostly a lightweight denim fabric.

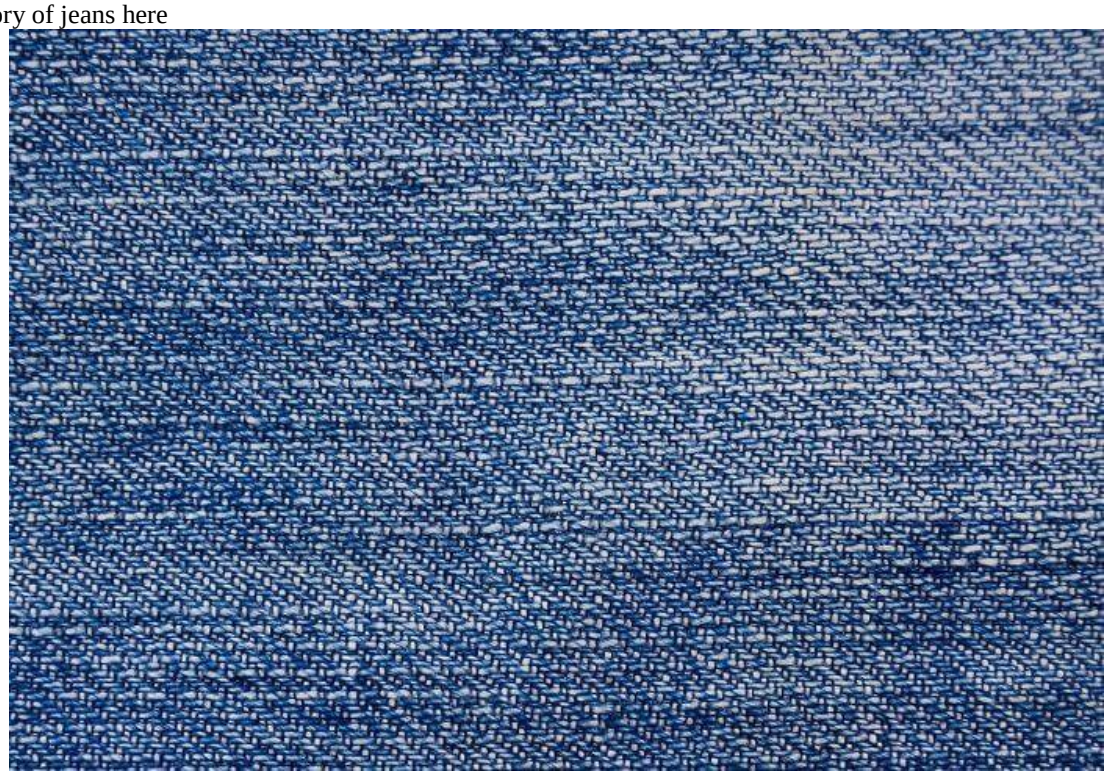
A special characteristic of twill weave denim is that there is a diagonal ribbing visible on the face of the fabric, which sets it apart from other cotton fabric. This is the result of the special twill weaving. Fibers are weaved on a loom in a twill weave pattern. The Twill diagonal weave of the denim fabric also gives it a good enough drape, especially for such a thick fabric.

Know more about 18 different types of fabric weaves here

Have you wondered why your jeans is white on the inside and blue on the outside?

It is because when weaving denim, Warp thread is dyed indigo whereas weft thread is left undyed. This special weaving in which colored thread (mostly indigo) is crossed with white thread results in a two-tone look which is very attractive. The color sits on the face of the fabric and the white pulls to the backside.

Denim was given the popularity it enjoys in 1873 by two Americans Jacob Davis and Levi Strauss. Levi Strauss was a cloth merchant and Jacob Davis a tailor. Jacob Davis got an order to sew up a pair of trousers which would wear well and be sturdy enough. Mr. Davis approached Mr. Staruss and purchased from him denim which was as sturdy as sturdy could be. Later they went on to form a partnership of making these same trousers which is known as jeans. Rest is history. You can read more of the history of jeans here



Different types of Denim fabric

1. 100% cotton Denim/Rigid denim

This is the normal denim without elastane fibers. This fabric is very durable, hard wearing and versatile.

2. Denim according to type of twill weave

This denim can have different twill weave patterns and thus vary in its structure. In a right hand twill, the twill line runs diagonally from bottom left to top right – this results in a

tighter woven fabric. Left-handed twill creates a softer denim. 3×1 and 2×1 weave are the most common twill weave. The best denim has a 3*1 twill weave ie. three warp threads to every one weft thread.

3. Raw denim

This is also called unsanforized denim or unwashed denim or Dry denim. This is a fabric which is not washed or treated in any way after dyeing.

The washing of denim fabric is usually done so that the fabric becomes soft and also to eliminate shrinkage. Basically what we call in sewing as pre-washing. Raw denim can shrink upto 20% in the first wash.

Raw denim has a very even look without any of the distressed look we are familiar in jeans. Whatever distressed look is desired will have to be obtained naturally by fading and stress. This is a natural process which some people consider more desirable than the factory made distressed look. It is important that you prewash raw denim before sewing / wearing.

4. Sanforized Denim

This is denim fabric which is processed so that it does not shrink after wash. Most of the denim other than raw denim is Sanforized.

5. Colored denim

There are two types of coloured denim – blue and the rest of the colours. The blue colour or shades close to blue is given with a process known as indigo dying. Sulphur dying and other dyeing gives denim other colours like Black, pink, grey, mustard, green, red etc. Tinting is done to give a deeper tint to denim.

6. Stretch denim

This is denim incorporated with stretchy synthetic elastane fiber like lycra/ spandex which gives it stretch. The stretch of the fabric will depend on the percentage of elastane in it. The elastane fibers are used as weft yarn.

7. Selvedge Denim

This refers to the denim fabric with edges which are finished with a band which is usually of colour orange or red. It is also called self-edge or selvage denim. This denim is very popularly assumed to be of better quality than other denim. Japan is the top producer of this type of denim fabric.

8. Lightweight denim

The kind of denim prefered for making blouses, and other summer clothes. This is usually denim in a plain weave.

9. Crushed Denim

This is a Denim fabric which is weaved and treated so that it looks permanently wrinkled or crushed.

10. Waxed reverse Denim

This is denim fabric which has a coating of wax on the reverse side for water resistance. It is mostly used to make outdoor gear and bags.

11. Polycore denim

This is a denim fabric which is a blend of polyester and cotton fibers. The blending results in a fabric with all the advantages of polyester and cotton – abosorbency, strength and wrinkle free.

12. Washed Denim

Acid washed denim is also called marble denim. This refers to a finish achieved in denim fabric using pumice stone soaked in chlorine. Colour of the fabric fades as a result of the abrasion with the stones and creates an attractive contrast with the indigo colour. The fabric is then rinsed, softened and dried. There are many other washes like enzyme wash, stone wash that the denim undergoes when it is made into your lived-in jeans.

13. Poly Denim

This is Denim fabric with a percentage of Polyester fibers blended in it. This fabric is very soft to touch, very easy to care for and stretches to an extent; it is very much popular to sew jackets, shirts, hats . The polyester blend adds to the durability smoothness and finish of denim.

14. Ecru Denim

Denim that has not been dyed indigo . This fabric has the natural colour of denim which is not dyed.

15. Bull Denim

This is a denim fabric which is very sturdy and tough because of its 3*1 twill construction. It is not as tough as canvas but it is very durable and heavy. Bull denim is used mostly for upholstery and home decor rather than for clothing.

16. Double dyed Denim

Denim yarns are dip dyed with Indigo dye. Double dyed denim is denim which is dip dyed more than regular denim (double the times) – this creates a very dark hue.

17. Thermo denim

This is also called double denim. This denim fabric has a lightweight fabric glued to the denim. This fabric makes the garment look like it is lined.

18. Denim according to the yarn

This denim can be categorized according to the yarn with which it is made. Open end yarn, ring spun yarn and double ring yarn are the most commonly heard terms. Denim made with ring spun yarn is considered the strongest. Open end yarn denim is the weakest.

19. Slub Denim

This denim is made of yarn with uneven thickness which gives it a different texture which is quite attractive.

20. Denim according to weight

This is a categorization based on the ounce weight of denim fabric per square yard. A heavy weight denim will be more than 10.5 ounce per square yard. A heavier weight denim will be more sturdy and durable. These are given in reference (3).

Characteristics of denim

i. Denim is one of the most demanding international commercial woven coarser fabrics
ii. Produced by 100% cotton yarn but you will find that there are a few denim fabrics mixed with spandex and polyester.
iii. It is made by twill weave.
iv. Warp yarn dyed by indigo dyes
v. The left yarn remains white/gray as its natural color
vi. Denim jeans are very strong and do not tear easily because it is long-lasting.
vii. It can be ironed at a high temperature
viii. It is a very durable fabric but after a certain time it fades
ix. It is durable, open, and temperamental
x. It is a woven fabric that is made by warp and weft yarn
xi. To control shrinkage, wrinkling, generally blended with spandex
xii. The mixed denim fabric has very good extensibility, comfortable wear for a slim figure.
xiii. Uses of Denim: Jackets, Jeans, Shirts, Skirts, Swimsuits, Belts, Handbags, etc.
These are given in reference (4).

Development of denim effect on knitted fabric

The use of technology and knowledge has made it possible to mimic and imitate the same appearance and properties in different products. Knitting technology and weaving technology are two different branches in fabric manufacturing technology, that can be now imitated in most cases to produce different types of fabrics. In the same way, knitting technology can now produce knit denim fabric with the same properties and appearance as that of woven denim fabric. This work, explores the field of creating knit denim fabric for diversified uses as well as fulfilling the purpose of woven denim. Research was carried out using single jersey circular knitting machine to create denim effect with knit and tuck loop separately. Two fabrics of GSM 290 and 270 were produced with excellent fabric quality.

Jeans made of denim have consistently been fashionable in worldwide culture and also have changed style significantly throughout the years. Denim was traditionally colored blue with “Indigo dye” to make blue “Jeans”, though jeans denoted a different, lighter cotton textile. Knitted fabric has certain special characteristics that make it suitable for creating a wide range of garments and accessories like tights, glues, underwear and other close fitting garments. Fashioning mark and fully-fashioned are two important features of knitted fabric, which can be related to fashion.

The traditional denim is hard- wearing, high-density fabrics with a high mass per unit area with a 3/1 or 2/1- twill weave and 1/1 chambrey construction. Besides classic indigo blue, denim is also dyed in other fashion shades and colors, the most popular being black denim. Denim is comfortable, fashionable, affordable and durable and popular in all age group.

Denim is conventionally made by a tatting method to create random knotting feature on surface and special color fading feature; features which make the denim garments popular all over the world. However the tatted denim is not as soft in texture and comfortable as fabrics made by a knitting techniques. Therefore due to the rigidity of the tatted denim, its application is limited in fashion design. The knitting method improves the softness and comfort ability of the fabrics and if indigo dyed yarn is used, color-fading feature is achieved on the denim.

The present work relates to the method of manufacturing denim, more precisely a method for knitting denim that has random knots and even twilling pattern in appearance.

Knit Denim Production Methods:

Both principal techniques, weaving and knitting are used to produce denim fabrics/denim effects on fabrics. Woven denim is conventional and vastly used by valued consumers while knit denim is novice but substantially preferable due to flexibility, user-friendliness and comforts. One of the research showed that "denim" effect on knitted fabric could be made from three types of technologies. They are:

- Float plated technology
- Thread fleece
- Interlock plaited jacquard

The structure using knit and float, using knit cams and sinker cams as well as sinkers to do a knit on one side of the fabric and a very tight float on the other where the float gives the woven effects. Depending on the cylinder cam arrangement, the machine generates the ability to do one-, two- and three-needle floats.

Materials, machines and methods:

a. Raw Materials

100% cotton combed yarn of 24/1s count and IPI value of 29.8 is used as raw materials and circular knitting machine as instrument is used in this experiment.

b. Knitting Machine Specification:

Machine type	: Single jersey Circular knitting machine
Brand	: Well Run
Model	: SHS-90
Cylinder Diameter	: 32″
Needle gauge	: 24 G
Number of feeder	: 96
Number of needle	: 2412
Rotation	:Anticlockwise

c. Method for creating knitted denim

The 1st step of the method involves dyeing the yarn with a dyestuff to obtain dyed yarn. Indigo dyeing as well as other dyeing i.e. reactive dyeing and sulphur dyeing can also be used for yarn dyeing of the fabric. The 2nd step involves knitting the foundation layer with grey/white yarn and front layer with dyed yarn to compose denim fabric. Here the front layer is tensely tautened in intermittence with a tensile force greater than the tensile force on the foundation layer to make the foundation layer have random knots. The next step involves washing of denim for creating fading effect if yarn dyeing is carried out using indigo and sulphur dye. Subsequently processes involved in finishing section like drying, compacting etc is carried out to achieve the best quality product.

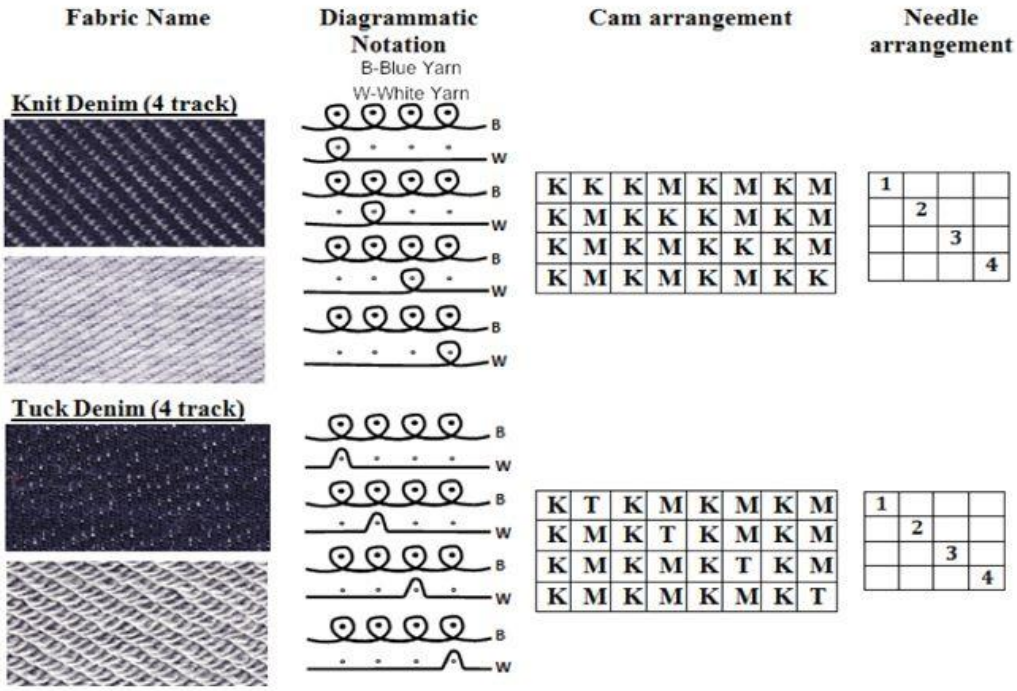


Figure: Needle and Cam arrangement for denim effects

Piece dyeing, cheese dyeing and rope dyeing are the conventional methods used for dyeing denim. One of the dyeing methods involved for the present experiment is rope-dyeing method for dyeing knitting yarn to improve fastness and even dispersion of the dyestuff. The rope dyeing is used to drench the knitting yarn into a tank for soaking dyestuff and then the excess dyestuff is removed by passing the knitting yarn through paired rollers as the excess dyestuff gets squeezed out and the process of drenching ad squeezing of yarn is repeated several times until the dyestuff gets properly attached to the knitting yarn. In case of indigo dyeing using rope-dyeing method each strand of yarn is dyed around the surface and thereby leaving the yarn with a white core. The strands of dyed yarn are evenly dispersed and wound onto a bobbin so as to avoid transversal or any discreteness in color during knitting and producing fabric.

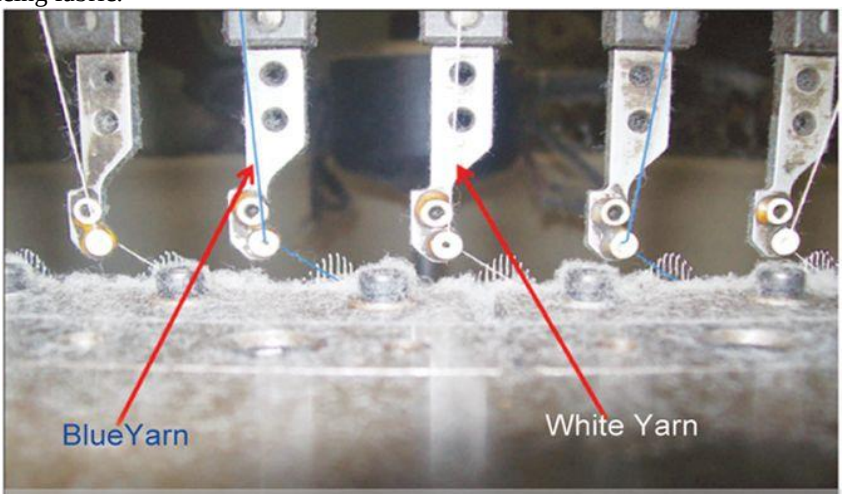


Figure: Yarn Feeding

In this experiment a circular weft knitting machine i.e a single jersey machine using the usual knit, tuck and miss cam is used to construct even twilling pattern on the fabric and perform a dual – plied denim including a foundation layer and a front layer on the fabric. The foundation layer is loosely knitted with variable tension/tensile force and a different stitch length than that of the front layer by adjusting the circular weft-knitting machine. Cam arrangements are set for creating terry twill effect and only twill effect on the fabric. The front layer is compactly constructed with high tension/ tensile force by adjusting the machine to a high-density program.

After tightening the front layer, the foundation layer is shrunk to create multiple knots on the foundation layer and thus denim is obtained. When the denim is used, the foundation layer having multiple knots serves as an outer surface to reveal the random knots in appearance. Correspondingly, the front layer serves as an inner surface. This pattern can also be achieved by using lycra yarn (acting in the front layer) along with the colored yarn so as to produce a compact structure by shrinking the inner layer thereby knitted denim is obtained.

Front Layer	Foundation layer
1st needle is fed with color yarn and adjusted stitch length=30mm/needle and tension= 3/4 cN	2nd needle is fed with grey yarn and adjusted stitch length= 1.35mm/needle and tension= 2 cN
3rd needle and odd number needles are fed with color yarn and adjusted stitch length=30mm/needle and tension= 3/4 cN	4th needle and even number needles are fed with grey yarn and adjusted stitch length= 1.35mm/needle and tension= 2 cN

Simultaneously a second experiment was conducted using knitting yarn dyed in sample dyeing machine using reactive dye, which offers excellent wash and light fastness properties. Also reactive dyeing is easier and cheap and its disability to produce faded denim fabric is alleviated by modern garment washing processes in which fading effects can be easily incorporated to finished fabric /apparel. Same parameter is maintained during knitting to produce knitted denim.

Total 6 kg fabric of two single jersey fabrics: Knit denim and Tuck denim were produced in a single jersey circular knitting machine with lycra attachment. The fabric produced has been passed through a stenter and compactor in order to heat set the fabric as well as the lycra. The fabric is then test in the best way and in the right condition.

Testing of physical properties of developed fabric

The fabric's physical properties like GSM, shrinkage and spirality as well as some chemical properties like color fastness to wash, color fastness to staining and color fastness to rubbing were measured for knit denim and tuck denim dyed with reactive dye.The resistance to the loss of color of any dyed or printed material during washing is referred to as its color fastness to wash. If dye molecule have not penetrated inside the inter polymer chain space of fiber with strong attractive force poor color fastness to wash result is found. For color fastness to wash test ISO 105 C06 (C2S) method was followed.

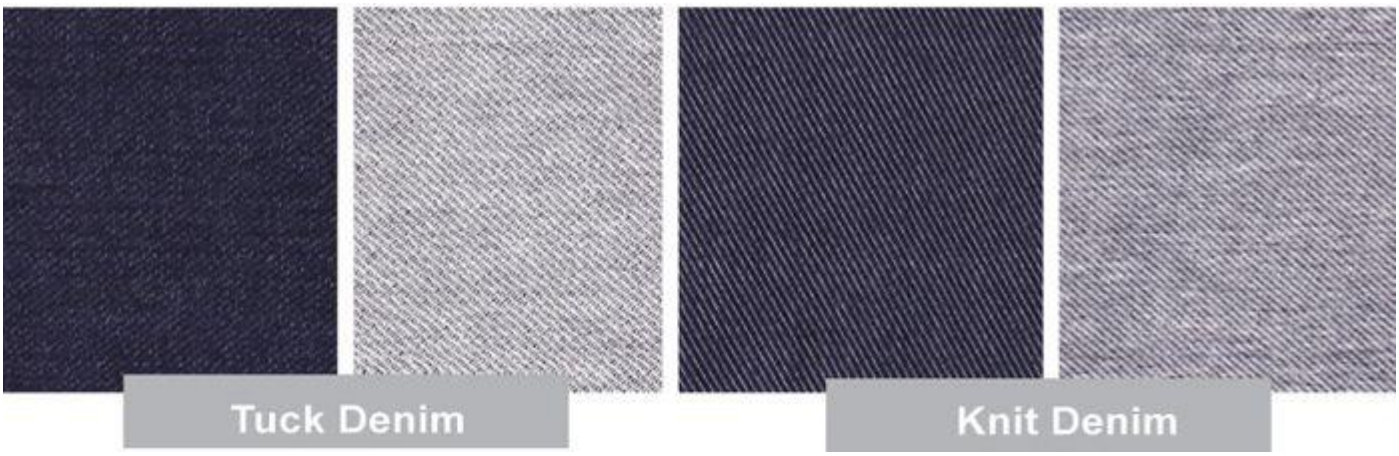
Color fastness to rubbing /crocking was designed to determine the degree of color which may be transferred to a specific pressure applied by crock meter. This test was done in both dry and wet state. The crocking cloth against which the test sample would be rubbed was a white, unbleached, undyed cotton fabric. In crocking cloth, 100% pick-up was maintained for wet rubbing. Color fastness to rubbing was tested by Crock meter in ISO105 X12: 1992 method.

Table 1: Technical Data for knit and Tuck denim

Fabric Name	Yarn Count	Dye Color	Shrinkage %		Spirality	Color Fastness To Rubbing		Color Fastness To Washing	GSM	
			Length	Width		Dry	Wet		Before Wash	After Wash
Knit Denim	24/1 Ne Lycra 40D	Reactive Blue	-5%	-5%	2.2%	4-5	4	4	263	270
Tuck Denim	24/1 Ne Lycra 40D	Reactive Blue	-5%	-5%	2%	4-5	3-4	4	284	290

Table 2: Data for color fastness to wash (Staining)

Fabric	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Knit Denim	4-5	4	4-5	4-5	4-5	4-5
Tuck Denim	4-5	4-5	4-5	4-5	4-5	4-5



Every sample when undergoes washing most of the cases they change their dimension. In general sense the changes in length or width of a fabric specimen subjected to specify condition is known as dimensional changes. The dimensional changes resulting in an increase of length or width is called stretched condition if the dimensional changes result in decrease of length or width is called shrinkage.

At first all the samples were conditioned for 4 hours in a standard temperature & RH% and the length and width of the samples were measured before washing. After wash, again the length and width of the samples were measured for identify the stretch or shrinkage%. Both the fabric showed same shrinkage during fabric testing.Spirality is a serious problem for plain knitted fabrics due to asymmetric loops. Spirality is described by the size of the angle made between the wales and a line drawn perpendicular to the courses. Spirality in a fabric is caused by the relaxation of torsion forces in the yarn which causes the individual fibres twisted round each other during spinning, to try and returns to their original untwisted state. It is known that a fabric knitted with a highly twisted yarn will have higher spirality. Also spirality increases with increasing the number of feeders. AATCC 179 method was used for measuring spirality.

The term GSM of fabric means the weight of the fabric in grams per square meter (Weight per unit area).

GSM is the most important parameter, which is maintained in the factory or industry. It is maintained in the all stages in the processing of knit fabric. It is also measured after dyeing, before dyeing and every stages of finishing process like stentering, compactingetc. GSM cutter measured GSM. Here grey GSM were measured in the knitting stages and finished GSM were measured after finishing for comparing them.

Technical Discussion

Shrinkage % for both knit denim and tuck denim is same in both lengthwise as well as in widthwise direction whereas spirality for knit denim is slightly more than tuck denim.Good washing fastness is seen for both the knitted fabric as the dye used was reactive dye and reactive dye makes a covalent bond with the fiber rather than forming a coating like that of indigo dye in denim fabric.It should be stated that dyeing with indigo dye may result in moderate washing fastness. GSM for the denim constructed with tuck loop shows more GSM compared to the other fabric. Tuck loop increases a fabric's GSM or oz/yd2 than a knit loop does therefore GSM of the tuck denim is more compared to a knit denim fabric. Knit denim is also eco friendly for human being as our skin comes in contact with the inner surface made of grey yarn rather than the outside which is dyed with indigo,sulphur or any dyes considered harmul for our body.

The two fabrics that got developed during experimental works are softer and comfortable as well as less complicated to be produced. Though only two fabrics of same count were being produced during this project work, scope remains for developing the fabric further in the future. Polyester can be used in alternate to cotton yarn to minimize cost and show different characteristics. Further developments such as knitting with rotor yarn during the production of knit denim and tuck denim by using half of the creel loaded with rotor yarn and feeding it to those feeders that undergoes less knitting action can surely open a new doorway for rotor yarn to be used in knitting. Slub yarn, neppy yarn, fancy yarn can also be used to make knit denim fabric of different appearance, feel and diversified usage. Knit denim is the fabric of the future, a future that we must understand and adapt so as to survive in this competitive market. These are given in reference (5).

2. Production of Knitted & Woven denim in Handloom, Power loom & Mill sectors

What is Denim?

Denim is a sturdy cotton warp faced textile in which the weft passes under two or more warp threads. This twill weaving produces a diagonal ribbing that distinguishes it from Cotton duck.

The most common denim is indigo denim in which threads are dyed while the weft thread is left white. As are the result of the warp faced twill weaving one side of the textile is dominated by the blue warp threads and other side is dominated by the White weft threads. This causes blue jeans to be white on the inside. The indigo dyeing process, in which the core of warp threads remains white, creates denims signature fading characteristics.

Denim manufacturing using conventional weaving

The weaving process interlace the warp are lengthwise indigo dyed yarn and the filling, which are the natural colored cross wise yarn. The warp threads are in the form of sheet. The weft thread is inserted between two layers of warp sheets by means of a suitable carrier, such as shuttle, projectile, rapier, air current, water current etc. The selection of carrier depends upon the type of weaving machinery used. The two different technologies available for weaving machines are conventional shuttle weaving system which is done by ordinary looms or automatic looms and shuttle less looms such as air jet, water jet, rapier loom, projectile weaving machines. The conventional shuttle looms results in lesser production due to slow speed and excessive wear and tear of machinery. As such now denim is generally woven through shuttle less weaving system.

Figure: Rapier weaving machine for denim weaving

Limitations of woven denim fabrics:

1) Fiber count- Knits denim are made of one continues thread. Woven fabrics are made of two sets of individual strands so we required additional preparatory process like warping, **sizing**, drawing in.

2) Stretch- Knit fabrics stretch because of the loops in the fibers. Woven fabrics do not stretch because their fibers run at 45 ‘ angles to one another.

3) Bias- Woven fabric have a visible bias on each piece matches when sewn. Knits do not generally have a nap.

Figure: Woven denim fabric

Knitted denim manufacturing

Denim effect on knitted fabric could be made from three types of technologies. They are float plated technology, Thread fierce, Interlock plated Jacquard.

The structure using knit and float stitch, using knit cams as well as sinkers to do knit on one side of fabric and a very tight float on the other where the float gives the woven effect. Depending on the cylinder cam arrangement, the machine generates the ability to do one, two, three needle floats.

Knit denim and tuck denim were produced in a single jersey circular knitting machine with lycra attachment. The fabric produced has been passed through a stenter and compactor in order to heat set the fabric as well as the lycra.

Figure: Single jersey knitting machine

Machine specification

1. Machine type- Single jersey circular knitting machine
2. Cylinder diameter- 32 inches
3. Needle gauge- 24 G
4. Number of feeder- 96
5. Number of needle- 2412
6. Rotation -Anticlockwise.

Machinery used for knit denim

1. Single jersey circular knitting machine
2. Sample yarn dyeing machine
3. Winding machine
4. Inspection machine
5. Hydro extractor (for yarn dyeing)
6. Dryer (for yarn dyeing)
7. Stenter (for finishing)
8. Compactor (for fabric)

Figure: Knitted denim fabric

Material required for denim knitting:

1. Yarn- 100% combed cotton yarn, ring spun yarn
2. Yarn count- 24 Be
3. CSP-242

Woven and knitted denim fabric property:

1. Knitted denim fabric show greater spirality compared to woven denim.
2. Good washing fastness for knitted fabric because of use of reactive dye makes covalent bond with t he fibre rather than forming a coating like that of indigo dye in denim fabric therefore the woven denim fabric dyed with indigo dye shows moderate washing fastness compared to the knitted denim.

3. GSM of knitted denim fabric is higher as compared to woven denim. GSM of denim woven fabric is low because after washing some size ingredients in the sizing removed during sizing.

Fabric name	Yarn count	Dye color	Shrinkage %		Spirality	Color fastness to rubbing		Color fastness to washing	Gsm		oz/yd^2	
			L/W	B/W		Dry	wet		Before wash	After wash	Before wash	After wash
Knit denim	24/1 ne lycra 40d	Reactive blue	-5%	-5%	2.2%	4-5	4	4	263	270	7.76	7.96
Tuck denim	24/1 nelycra 40d	Reactive blue	-5%	-5%	2%	4-5	3-4	4	284	290	8.38	8.56

Figure: Test result of knitted denim

In above study it is clear that knitted denim gives a good performance compared to woven denim with low manufacturing cost. These are given in reference (6).

Handloom Sector Woven Denim

Machine cost	= Rs. 6750-25000-(14000/12)/Month
Labour cost	= Rs. 35/per metre x 3 = Rs. 105/day 3m/day
Material cost (Yarn)	= Rs. 375/kg
3m^2/day gms/day	= 3 x 200 = 600 gms/day
200 GSM	
Machine cost depreciation/day	= 14000/(10x12x30) = RS.3.9/day
Material cost 0.6 x 375	= Rs. 225/day
Labour cost	= 3x 35 = Rs. 105/day
Cost of production/day	= Rs. 333.9/day
For 3m^2 fabric cost of production/day/m^2	= Rs. 111.3/day

Power loom

Cost of machine	= Rs. 8,50,000
30 machine labour cost	= Rs. 500 per machine = 500/30
Material cost	= Rs. 375/1kg
Production/day	= 48kg/machine
Power consumption	= 1 Hp
Machine cost depreciation / day	= 8,50,000/(10x12x30) = Rs.236/day
Material cost	= 48x375 = Rs. 18,000/day
Labour cost	=500/30 = Rs. 16.7
Power consumption	= 746w x 24 = 17904 watts/day
Power cost (Industry)	= Rs. 5.51
Total power cost	= 17.9x5.51 = Rs.98.6/day
Total cost/day	= 236+18,000+16.7+98.6 = Rs. 18,351.3/day
M for 48 kg (200 gsm)	= 1 x (48000 gms/200) = 240m^2
Cost for 1m^2 of fabric	= (18,351.3/240) x 1 = Rs. 76.5

Mill Sector

Cost of fibre	= Rs. 35/kg
Yarn cost convertion	= Rs. 2/kg of yarn
Waste %	= 3+5+0.5+0.5+18%+0.5+3+1 = 31.5%
Cost of yarn	= (1+0.315)x35 = Rs. 46/kg
Cost of dyeing	= Rs. 170/kg
Cost of dyed yarn	= 170+46 = Rs. 216/kg
The material cost is less for mill sector.	
Other costs are same as in power loom sector.	
Total cost/day	= 236+48x216+16.7+98.6 = Rs. 10,719.3/day
Cost of 1m^2 of fabric	= (10,719.3/240)x1 = Rs. 44.7

Cost of production of knitted denim

Cost of machine	= Rs. 2 lakhs
Labour cost	= Rs. 200/shift
Labour cost	= Rs. 8000/month
Production	
In knitting for 8 hrs	= 88 kg
No. of machine for labour	= 1
Material cost/shift	= 375 x 8 = Rs. 33,000/shift
Material cost/day	= Rs. 99,000/day
Power consumption	= 1.4 kw/hr
Power charges	= RS. 5.51x1.4 = Rs. 7.714/hr

Power charges for one day	= 7.714x24 = Rs. 185/day
m^2 for 88 kg x 3	= (88000x3)/200 = 1320 m^2
Total cost /day	= (200000/(10x12x30))+(8000/30) + 99000 +185
	= 55+267+99000+185
	= 99507
Cost for 1m^2 of fabric	= 99507/1320 = Rs. 75.38

3. Problems in Knitted Denim

When we talk about knit fabrics, an important question to ask is:

Why does the factory merchandiser run to buyers for last minute approvals after the bulk fabric is in house?

The answer is simple:

Because the fabric received will have some problem or the other.

Let's look at some of the major fabric quality issues which come to the Buyer's notice for approval regularly.

Some of the other fabric quality issues may be Dyeing patches, Softener marks, Barriness, Crease marks, Skewing, Bowing, Contaminations, Needle/Sinker lines, thick and thin places in yarn, loose fabric structure, Oil Stains etc.

These are evaluated physically in the fabric warehouse. If the above quality issues are noticed, then the fabrics are sent for re-processing or get rejected. Often these issues are not brought to Buyer's notice.

In knit fabrics, GSM is a very important factor for determining fabric quality. GSM is influenced by Stitch Length (Loop Length) , Machine Gauge, WPI, CPI, Yarn Count, etc. Sometimes the in-housed bulk fabric has visible difference in the density, either within roll or from roll to roll.

Variation in parameters during knitting, dyeing, stentering, compacting, etc. may lead to this issue. Sometimes yarn count allowances & loop length variances may also lead to this issue. Usually, the buyers give an allowance of + or – 5%. In cases where the variation is above the allowance, the buyers approval is obtained.

"Once, a fabric manager worked tirelessly the whole night and inwarded a viscose jersey fabric for SMS. He found 8% lesser GSM. The buyer came to inspect the fabric next morning. The fear on the fabric manager's face turned into a smile when the designer felt the fabric. Though the GSM was less compared to the approved standard, she loved the hand feel & the fall of the fabric. An on the spot approval by her, set the production rolling"

Dimensional Stability

Knit fabrics by nature are unstable compared to woven fabrics. The main cause of failure in dimensional stability (i.e., Shrinkage) is due to high physical stress & strain exerted on the fabric during the whole process flow of making knit fabric. The fabric may not have been processed in relaxed state; or not allowed to relax properly after compacting. Knitting with high tension, knitting machine diameter, over loading in soft-flow machine, improper stentering or compacting without checking trial shrinkage reports, yarn parameters, etc. are also causes of shrinkage failure. It may depend on the structure of various knits and yarn count/machine gauge selected for a particular GSM of fabric. Improper heat-setting of stretch and poly fabrics will result in dimension stability problems. It is also based on the fibres used like cotton, poly, nylon, viscose, elastane or blends, etc.

Though many routes are followed to control the shrinkage in knitted fabric, mainly it is based on the end product. If the final product is a basic piece dyed T-shirt, then the fabrics are properly compacted, relaxed for some time and internal test reports are checked before cutting. But if the final product is garment washed or the garment dyed then panel wash process is followed in some regions or double compacting/adding allowance in the pattern are followed to control shrinkage. Even though every buyer gives shrinkage allowance based on knit structure between 5 and 7 %, usually there will be an exemption request from the manufacturer.

Surface Appearance

Hairiness and Pilling are the two factors considered in the surface appearance. Hairiness is fiber ends and loops protruding from the body of the yarn. Pilling is the formation of little balls of fibers due to abrasion and handling of fabric in various manufacturing processes. Yarn quality defines the hairiness level in it. Compact yarns are less hairy, while carded yarns are more. When a good quality yarn is used, the fabric is automatically good too. Now-a-days bio-wash is done to cut the hairiness on the surface, but extensive bio-wash will reduce the GSM and strength of the fabric and many times colour tone of the fabric is changed. Pilling is tested and is rated on a scale of 1 to 5.(1 is severe pilling and 5 is no change.). Pilling is not a desirable property because aesthetically the surface does not look good.

Hairiness may be desirable in certain situations and undesirable in some, based on the end use and application of the garment. Many western customers like mild hairiness in order to give the fabric soft hand feel. However Indian customers prefer the clean surface. Even though every buyer gives the requirement and fabric standards clearly, mostly there will be an exemption request from the manufacturer.

Hand-feel

This is an important and subjective factor of the knit fabrics. Though there are tests to measure hand-feel scientifically, it always depends on the person feeling it. Satisfaction of any customer first comes from the touch & feel of the garment. Garment feel is an important factor, which drives a customer to make a purchase. Right from the fibre & yarn quality to finishing, every process has an impact on hand feel Physical standards (fabric swatches) are provided by all the buyers to understand the hand-feel requirement of each fabric quality or for each style.

Though customers like soft hand-feel, but sometimes (based on the usage) they like dry touch, soapy touch, rough feel, prickly feel, etc. Required hand-feel is applied in many ways, but mostly softener treatment is given at the last stage of processing. Bio-wash and silicon softener gives a very soft touch but leads to hairiness on the surface. Hand-feel is also largely based on the fabric's fibre content.

In a graphic printed T-shirt, base fabric will have rougher hand-feel in order to get better print fastness. This is overcome by treating the garment with softener. All Over Printed (AOP) fabrics are treated and finished with softener once printing is completed which gives them a very soft hand-feel. Since its subjective, the QA may reject the fabric based on their understanding. A factory merchandiser, in such a scenario will submit a swatch to the Buyer and opt for an exemption.

"All Over Printed camouflage fabric with 100% print coverage will always be rough in hand. It is always better to dye the lightest colour in artwork & print rest of the colors. If needed, fabric can be washed before compacting. This is one of the ways to get a better hand-feel of AOP camo."

Colour Fastness

Colour fastness is the extent to which a fabric loses its colour or fades under certain conditions in water, exposure to sunlight, body perspiration, abrasion to its own surface or other surface, laundering, pressing etc. Right from fibre and fabric properties, structure and characteristics of dyes used, quality of dye and auxiliaries selected, process parameters, colour tones, pre-treatment to the fabrics before dyeing, fixing of colours after dyeing, finishing process of fabrics etc. determines the colour fastness. Dark colours tend to bleed in water, some colours fade in sunlight and few colours cannot withstand laundering. Right dye selection, further processes involved, final apparel usage and maintaining proper process parameters will lead to better color fastness. Even though every buyer gives the requirement ratings very clearly based on the end-use, test may fail with 0.5 point variance and always there will be an exemption request from the manufacturer.

Practically, it is not possible to completely avoid these common issues in knit the common issues in knit fabric manufacturing cannot be completely avoided. However, care can be taken at every step to minimise the quality issues. These are given in reference (7).

4. Testing of Knitted denim

The knitted denim is collected and it is tested for fabric stiffness, crease recovery drape and other quality particulars. It is given below.

Bending

Bending length (Course wise length) c = 5 cm
Bending length (Walewise length) = 3.5 cm
Knitted denim = 150 – 200 gsm
Flexural rigidity = $3.39 \times w_1 c^3$ mg cm
= $w_2 c^3 \times 10^3$ mg cm

c- Bending length in cm
$c = l\, f(\Theta)$
$f\ \Theta = [(\cos ½\ \Theta) / 8 \tan \Theta]^{1/3}$
w_1 = weight/sq.yd of fabric in onces
w_2 = weight/sq.cm of fabric in gms
overall flexural rigidity $G = (G_w G_f)^{1/2}$
bending modulus $q = 732\ G/g_1^3$ kg/sq.cm = $12G \times 10^{-6} / g_2^3$ kg/sq.cm
g_1 – Fabric thickness on thousands of an inch
g_2 – Fabric thickness in cm
thickness = 0.468 cm
white stitch length = (0.385/16) x 25.4 = 1.35 mm
blue stitch length = (0.6/16) x 25.4 = 0.95 mm

D.C.F. Front = (460- 176.625) / (706.5-176.625) = 0.5348

Knitted Denim

1. Courses/inch = 64
   Wales/inch = 36
2. Crimp % white = (0.85-0.5)/ (0.5) x 100 = 70%
   Blue = (0.6-0.5)/ (0.5) x 100 = 20%
3. Stitch length white = 1.35 mm
   Blue = 0.95 mm
4. Count = 20^3
5. GSM = (64x36x(1.25/25.4) x 453 x 100 x 100) / (2.54x2.54x20x36x840) = 132 g/m^2
6. Structure = Twill

.	X	X	X	**Single Jersey**
X	X	X	.	**. Blue Colour**
X	X	.	X	**X White Colour**
X	.	X	X	

Crease Recovery

1. Course – Face - 70^0
   2" wales 1" – Back - 210^0
2. Wales – Face - 29^0
   2" course 1" – Back - 120^0

5. Washing of Knitted denim & Woven denim and compared to socks

The knitted denim and woven denim are washed for five times and socks is also washed for five times and the result is given in table.

	L	W	L	W	L	W	L	W	L	W	L	W
Socks Ribwelt	3	12	3	12	3	12	3	11.5	2.5	11.5	3	12
Calf or leg	18	12	18	12	18	12	17	12	17.5	12	18	12
Foot	18	11	18	11	18	11	17	11	16	11	16	11
Denim woven	106	21	107	21	106	21	106	21.5	105	21.5	105	21
Denim knitted	34	54.5	33	54	34	54	33	54	33	53.5	33	54

6. Result

Bending, Drape-co-efficient crease recovery & washing of knitted and woven denim

Graphs

Y axis – Length, Width (cm)

X axis – no of washings 0 to 5

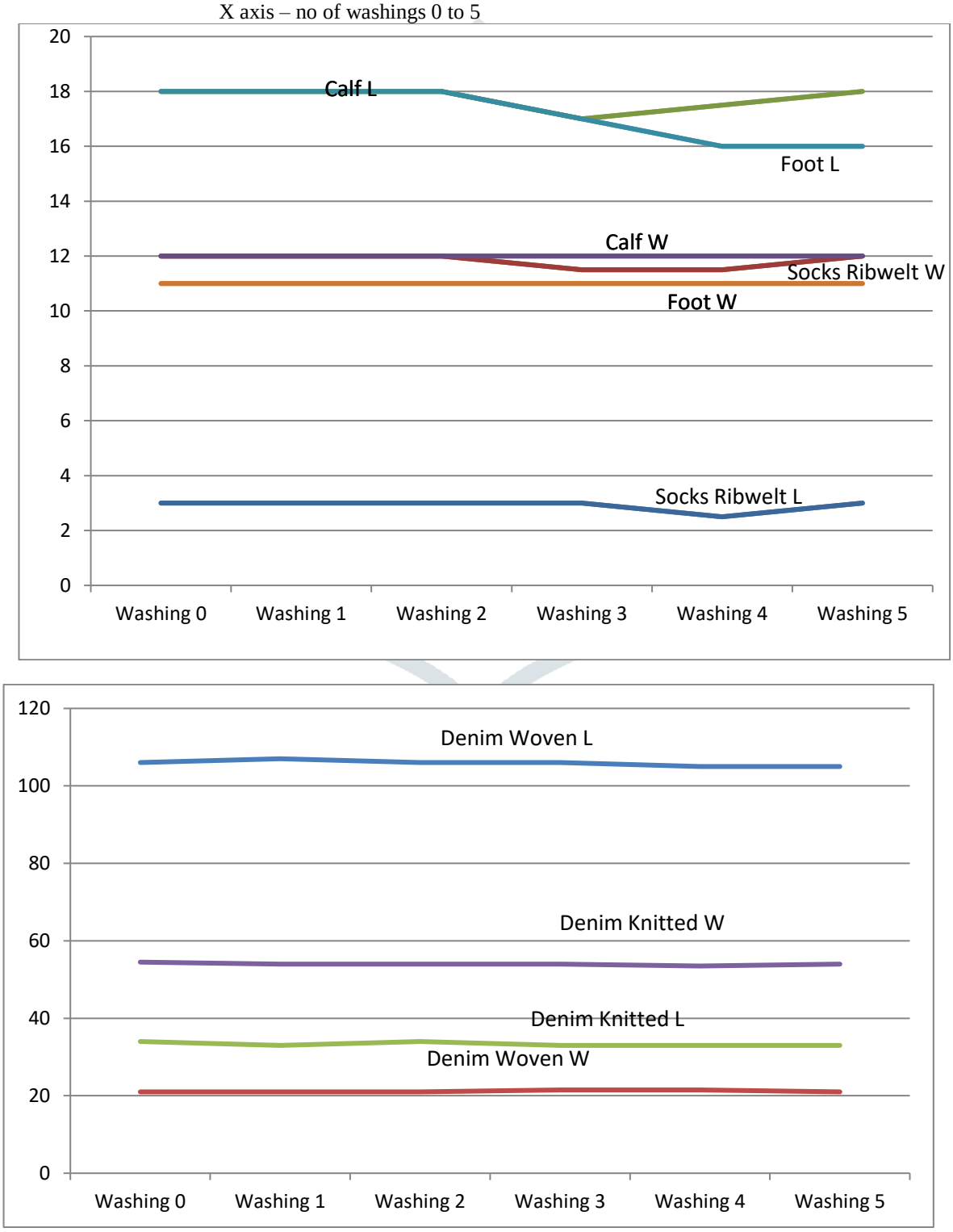


Figure 1. Woven denim

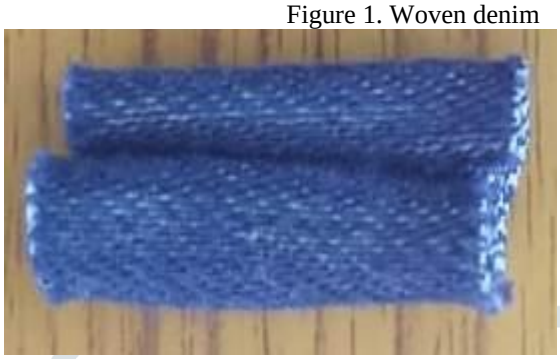


Figure 2. Crease recovery sample walewise

Figure 3. Crease recovery sample coursewise

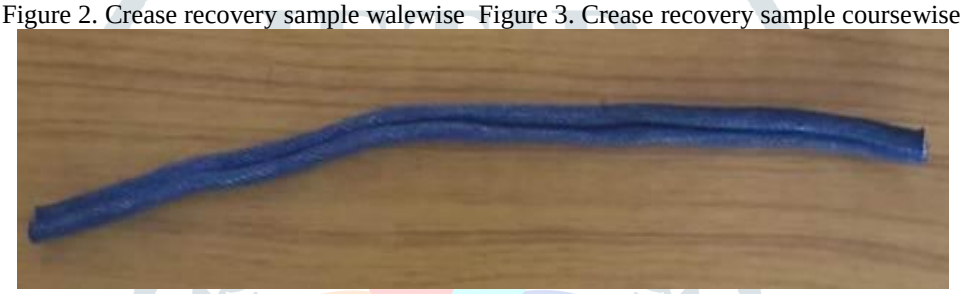


Figure 4. Bending length sample coursewise

Figure 5. Bending length sample walewise

Figure 6. Drape sample face side Figure 7. Drape sample back side

Figure 8. Washing sample (Length & Width)

Figure 9. Socks sample (Length & Width)

7. Discussion

Bending property

The bending property is analysed in Shirley stiffness tester. The bending length for knitted denim is found to be 5 cm for coursewise length. The bending length for wale wise length is 3.5cm. This means that the fabric bends in course wise direction more than walewise direction. The maximum value of bending length is 8 cm & minimum value is 0cm. since the bending length is between 3.5 and 5cm it can bend according to body shape. Over bending is not there because it is above 0-3.5cm. Hence it is best suited for dressing purpose.

Flexural rigidity

The flexural rigidity determines the force at which the material flexes. Using bending length, weight/sq.cm flexural rigidity is found out. The flexural rigidity (G) is calculated in wale and course wise direction. Overall flexural rigidity is obtained by using the formula. Maximum flexural rigidity is 15,360 mg cm and Minimum flexural rigidity is 0 mg cm.

The length wise course flexural rigidity is 1875 and lengthwise wales is 643.125 mg cm. This means that the fabric flexes more easily and its value is very low. So some arrangements has to be provided to improve its rigidity values. Use of elastocene or Lycra or Spandex yarns may make it very stiff and flexural rigidity can be increased.

Bending modulus

The bending modulus determines how flimsy the fabric reacts to its own weight. Using the bending length, bending modulus can be deduced. The bending modulus requires flexural rigidity values and the thickness of fabric. The maximum bending modulus is 1.8 kg/cm^2 and minimum is 0.

The bending modulus for lengthwise course sample is 0.22kg/cm^2 and for lengthwise wales is 0.0753 kg/cm^2. The bending modulus should be above 0.45kg/cm^2. So the bending modulus is poor for knitted denim. To have good bending modulus the fabric should be given elastocene or lycra or spandex fibres which enables it to produce good bending modulus.

Drape Co-efficient

The drape is calculated in drape apparatus in laboratory. The maximum value is 1 and minimum value is 0. The drape co-efficient for front side of knitted denim is found to be 0.5348 and for back side of knitted denim is 0.6282. This value is good. So knitted fabric drapes very well over the body curves.

Crease Recovery

The crease recovery test is carried out in the laboratory. The crease recovery angle for the sample course 2" wales 1" is 70^0 for face side and 210^0 for back side. This value indicates higher angle of crease recovery. This means the crease made over fabric is quickly recovered. The crease recovery angle for the sample course 1" wales 2" is 29^{0}for face side and 120^0 for back side. Here also the fabric experiences higher crease recovery. For formal wear crease should be made & it should be permanent. So the knitted denim could be used for casual wear. The crease recovery angle can be improved if the stiffness is increased. By introducing spandex or elastocene or lycra fibres the crease recovery can be improved. Crease recovery angle should be between 45^0 and 135^0 for good fabric.

Washing treatment for knitted and woven denim

Knitted denim and woven denim is subjected to washing treatment for 5 washings. The dimensional changes for coursewise and walewise for knitted denim and warpwise and weftwise for woven denim is measured using tapes. The socks sample of knitted is also subjected to washings for 5 times and its dimensional changes were measured.

For knitted denim the wale wise change in dimension is not much. It is around 1 cm only. The coursewise dimensional change is also not much. It is around 1 cm only. Compared to socks sample the dimensional stability is poor. For socks sample dimensional changes is 0 cm. To have good dimensional stability spandex or elastocene or lycra yarn can be introduced to some extenet.

8. Conclusions

Knitted denim is found to be very profitable. The production of knitted denim is Rs. 99000/day compared to woven denim which is Rs. 18000/day. The profit is more for knitted denim manufacture. Some treatment can be given with innovative ideas which improves bending and crease recovery property of knitted denim. The various methods like spandex or lycra or elastocene yarn introduction, Tuck and miss stitch combination, Altering many design which produces good bonding and crease property will make knitted denim more suitable for wear.

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10. Acknowledgement

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