EFFECT OF LYCRA AND NYLON YARN PERCENTAGE ON THE DIMENSIONAL AND PHYSICAL CHARACTERISTICS OF LOCKNIT WARP KNITTED FABRICS

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Abstract

The effects of different percentages of elastane and Nylon yarn on the dimensional and physical properties of elastane/Nylon Locknit warp knitted fabrics are investigated. In order to investigate the properties of the fabric, four different samples were knitted by selecting four different run-in ratios of elastane and Nylon. Elastane yarn was kept at a constant elongation of 65% for all four samples. Two samples were produced keeping constant run-in of nylon yarn and changing the run-in length of elastane yarn. Then elastane yarn run-in was kept constant and produced two other samples.

The sample with minimum run-in length of elastane yarn and the highest run-in ratio has the highest value of load at 20%, 40%, 60% and 80% extensions in length direction and the lowest values of load at 20%, 40%, 60% and 80% extensions in width direction. This is due to the fact that low run in of elastane yarn increases the strain on the yarn and it increases the tightness factor value of the sample and contributes higher load at extension along the length direction of the greige sample. Nylon yarn runner length influences the relaxation behavior of elastane yarn and it leads to reduce the load at extension along the width direction of the sample.

Changing of Nylon yarn runner length influence the relaxation behavior of elastane yarn and it has an effect on the load at different extension in width direction and course density of the greige fabric. Results revealed that the effect of elastane content of the sample is more on the load at extension values than the effect of run-in of the Nylon yarn.

Key words Greige fabric, Run-in, elongation, load at extension. course density

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
%	Percentage
o	Degree of Temperature
C	Centigrade
F	Franhide
ASTM	American standard of textile material
b_g	Back guide bar
CPI	Courses per Inch
GSM	Gram per square meter
g/m^2	Gram per square meter
f_g	Front guide bar
K	Tightness factor value
LTD -03	Limited brand stretch & recovery test
l	Stitch Length
l_f	Stitch Length-front guide bar
l_b	Stitch Length – back guide bar*l*
S	Stitch density
WPI	Wales per inch
CPI	Courses per inch
T	Yarn count in Tex
T_f	Yarn count in Tex – front guide bar
T_b	Yarn count in Tex – back guide bar
SLS	Sri-Lanka standard

T_1G	Sample which is having Run in ratio 2.5:1(1400:550) - Greige
T_2G	Sample which is having Run in ratio 2.8:1(1400:485)- Greige
T_3G	Sample which is having Run in ratio 2.3:1(1330:580)- Greige
T_4G	Sample which is having Run in ratio 2.4:1(1330:550)- Greige
T_1F	Sample which is having Run in ratio 2.5:1(1400:550) - Finish
T_2F	Sample which is having Run in ratio 2.8:1(1400:485)- Finish
T_3F	Sample which is having Run in ratio 2.3:1(1330:580)- Finish
T_4F	Sample which is having Run in ratio 2.4:1(1330:550)- Finish
G_E	Greige Sample – Width Direction
G_L	Greige Sample – Length Direction
F_E	Finished Sample – Width Direction
F_L	Finished Sample – Length Direction

CHAPTER 1: INTRODUCTION

1.1 Background of the study

In recent years there has been a very fast growth in the knitting sector of the textile industry. Further revolution in the fashion knitwear industry has become inevitable due to the frequent changes in fashion trends, leading to the production of knitted apparels using different yarn types, fabric types, designs and style variations. Different types of yarns and fabrics play a very significant role in fashion trends, especially in segments such as casual wear and sportswear, because consumers expect performance of garments such as sportswear rather than fashion (Mona M.A. Haji,, 2013).

The requirements of performance characteristics in terms of function and wearing comfort of swimwear, leisurewear and sportswear have increased with the growth of a textile Industry. According to the construction method of knitted fabrics either warp knit or weft knit, that always have a certain stretch and elasticity property. Warp knitting technique is capable of producing fabrics with varying elastic behavior. However,. the recovery power of warp knit fabrics is generally not sufficient for garments mainly used for sports activities. Hence stretch and recovery behavior of the warp knitted material could be enhanced by introducing the elastane yarn. Elastane (spandex) was first developed in 1959. (Cooke.W.D and Assimakopoulos.G.S, 1985). Elastane yarn is capable of imparting stretch and recovery property to the fabric. Therefore apparel manufacturers who makes swimwear, leisurewear and sportswear are preferred to use stretched warp knits fabrics rather than the weft knits because of its functional properties (Senthilkumar.M,Sounderraj.S and Anbumani.N, 2012)

Currently there has been tremendous growth in stretch warp knitted fabrics. Why this phenomenal demand for stretch? It is like putting reinforcing rods in building walls, you cannot see them but they give integrity to the product". Spandex add enough stretch to fabrics to provide comfort (Borland, 2000).

Fabrics containing spandex yarn have a wide application value, especially because of the increased extensibility, elasticity, high degree of recovery, good dimensional stability and good shape retention, soft and smooth handle and simple care.(Serkan Tezel and Yasemin Kavusturan, 2008). Today spandex is blended with every other fiber, natural or man-made. It is even applied to leather for suppleness and comfort. Even small amounts of spandex (2 to 5 percent) give better performance of the fabric. Higher quantity is used for intimate apparel, athletic wear and swimwear. Jan Nolan, marketing and merchandising manager, Bayer Fibers, has stated that "The consumer understands the benefits of spandex.So there is a considerable greater demand placed on the stretched warp knitted fabrics compared to no stretch material.(Borland, 2000). Hence dimensional stability of knitted fabrics has been one of the most discussed topic in the apparel industry as well as research fields as the dimensional instability of a knitted material directly affect its end use. According to the textile terms and definitions, dimensional stability of the textile material is to maintain or retain to its original geometric configuration. Stretched warp knitted fabrics are mainly used for underwear and sportswear, because stretched warp knitted fabrics ensure stable shape of body under loads in wearing for the body confirming garments as mentioned above.(Jelka Gersak, Dunja Sajn and Vili Bukosek, 2005) Therefore dimensional stability of a stretch warp knitted fabric is a very important factor to ensure the body shape.

Dimensional stability of stretched knitted fabrics are mainly determined by the knitting geometrical parameters such as yarn type, machine parameters and knitted fabric parameters. Variation of above mentioned parameters significantly influence dimensional stability, performance, comfort and aesthetic properties of knitted fabrics. The knitted fabric parameters which influence dimensional properties of elasticized single knitted fabrics are, knitted structure, wales and courses density and loop length.(Alenka Pavko Cuden, 2013).

problems created due to poor fabric quality verses performance characteristics of stretched fabrics during fabric selection stage, specially the dimensions and elongation parameter of the stretched material. Most of the time stretched material does not meet the required quality standard specified by the customer due to inconsistency of the quality standard of the finished fabric. Therefore it increases the lead time of fabric selection and remanufacturing processes and finally it affects total delivery time of the finished product. Fabric remanufacturing process is mainly driven by trial and error method. Technical data which is used for fabric remanufacturing process are based on the past experience and records, due to lack of scientific knowledge on the behavior of stretched warp knitted fabrics. There is no enough information or data enable to determine the necessary elastane yarn consumption to achieve the desired fabric properties such as fabric elongation, weight and fabric width. So if there is a method to predict the performance characteristics of warp knitted fabric based on the proportion of elastane and Nylon yarn, it would help to reduce the lead time of fabric remanufacturing process. Finally it would be able to achieve the target of shorter delivery time of finished product.

Although the dimensional instability of a stretched warp knitted materials is a critical factor there is very few published work available. Mainly they have discussed on the comparative elastic properties of different warp knitted fabric structures. Further few researches investigated the elongation behavior of warp knitted fabrics which knitted with different structures. Some researches available in literature described the relation between the fatigue behaviors of warp knitted fabrics under cyclic tension. However many researches have been carried out on the behavior of dimensional changes of stretched weft knitted single jersey knitted material.

Problem statement

The researchers have done many studies on the elongation behavior of warp knitted fabrics It is hardly find any research related to the elongation behavior of Locknit fabric with elastane yarn when changes the Nylon and elastane content by changing run- in ratio of two guides.

1.3 Objectives of the study

The main objective is to investigate the effect of percentage contents of Nylon& elastane of Locknit warp knitted fabrics on dimensional and physical properties such as GSM, Load at different extensions, fabric width and bursting strength of the fabric, while achieving the main objective of the study, following sub objectives of the study are also identified.

- to investigate the highly influential physical parameter which changes while the percentages of elastane and nylon contents are changed of Locknit fabrics
- to investigate the influence of elastane& nylon contents of the warp knitted Locknit fabrics on fabric properties
- to optimize the percentage contents of Nylon& elastane of Locknit warp knitted fabrics to achieve the desired dimensional and physical properties such as GSM, load at different extensions, fabric width and bursting strength of the fabric.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents related literature of warp knitted fabrics which knitted with elastane yarn and their performance. Most of the literature available is related to the single jersey weft knitted structures with elataine and the effect of elastane content on their performance characteristics. Relatively little work has been done to study the effect of elastane on the performance of the warp knitted fabrics. This chapter also describes the warp knitting structures, their geometry and quality parameters. Further it investigates recent studies of new development of spandex and properties of nylon 6.6 yarn.

2.2 Introduction to warp knitted fabric

Knitted fabric is a three dimensional structure made by means of needles forming a series of interlocking loops. The basic constructional element of knitted structure is a loop. Knitted fabrics can be subdivided into two main groups as weft and warp knits, depending on the way the stitches are formed. In weft knitted fabrics the stitches are made across the width of the fabric. In warp knitted fabrics the loops are made from each warp yarn along the length direction of the fabric (Raz.S, 1987). The rows of knitted loops across the width of the fabric are called courses and the columns of loops along the length of the fabric are called wales (Raz.S, 1987). Figures 2.1 and 2.2 show the yarn movement in warp and weft knitted structures respectively.

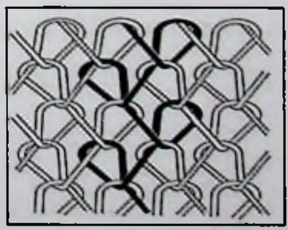

Figure 2.1: Warp knitted structure

Source: RAZ.S, 1987.

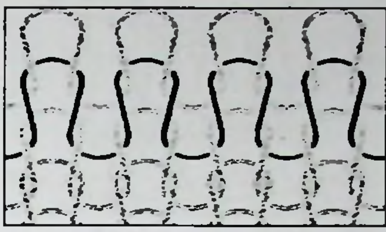

Figure2.2: weft knitted structure

Source: Raz.S,1987.

The warp knits are made on two basic types of warp knitting machines known as Tricot and Raschel knitting machines. The warp knitted structures require a set of yarns fed from warp beams, each yarn producing a column of loops along the length of the material. The fabric is formed when the yarns are moved from one needle to another on successive courses. Each warp set is controlled by yarn guides mounted on a guide bar as shown in Figure 2.3. The number of guide bars determines the number of warp sets. The number of guide bars may vary according to the structure to be produced. When the machine has more than one guide bar, yarns of different types may be fed and can get various structures of warp knitted fabrics (Aanad, 2000).

2.2.1 Formation of loop structure

The warp knitted loop structure is made up of two parts. The first one of them is the loop itself, which is formed by the yarn being wrapped around the needle and drawn through the previous loop. This part of the structure is called the overlap. The second part is the length of yarn connecting the loops, which is called an underlap. It is formed by the shogging movements of the guides across the needles (Raz.S, 1987). Figure 2.3 shows swing and shog action of a guide bar.

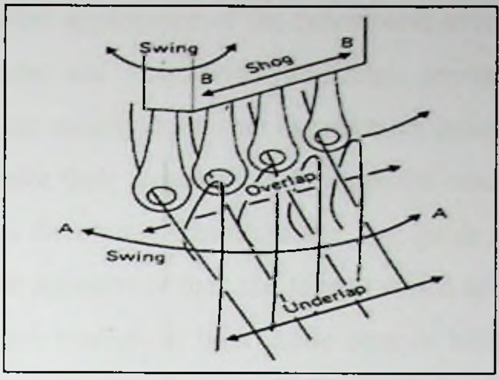

Figure2.3: Shogging and swing action of a guide bar
Source: David J spencer, 2001.

2.2.2 Open and closed lap

Two different lap forms are used in warp knitting; depending on the way the yarns are wrapped around the needles to produce an overlap.

When the overlap and the next underlap are made in the same direction, an open lap is formed. When closed lap is formed overlap and the following under lap are moved in opposite directions. The most commonly used lap is the closed lap and open lap is used when special need arise, because it affects the fabric properties greatly (Keyzer, 2011).

2.2.3 Types of warp knitted fabrics

Two main types of warp knitted fabrics can be identified as single guide bar and two guide bar fabrics. Although it is possible to knit fabrics using a single fully threaded guide bar, such fabrics are not in great demand because of the limited number of effects which can be produced, fabrics have poor covering properties, dimensionally unstable and split easily when damaged (Raz.S, 1987).

But such fabric could be used to produce fabric structures that are components of warp knit spacer fabrics (Shanna. M and Gary Smith, 2005). In addition some distortion arises due to the inclination of loops, each course showing a definite bias either to right or to left, depending upon the movements of the guide bar.(Aanad, 2000). Figure 2.1 shows the inclination of loops of single guide bar fabrics.

In order to achieve a better appearance of the fabric with erect loops and to get more stable both the widthwise and lengthwise properties, second set of warps can be employed. This second set usually makes an opposite shogging movement to the first. So the two guide bars make their underlaps in the opposite directions and equal tension will be imposed in both directions. Therefore the two guide bar structures are more stable and have the better appearance than the fabrics which are produced by the single guide bar. When the yarn tension in both guide bars is balanced the loops will be upright (Raz.S, 1987). It can be seen in figure 2.4

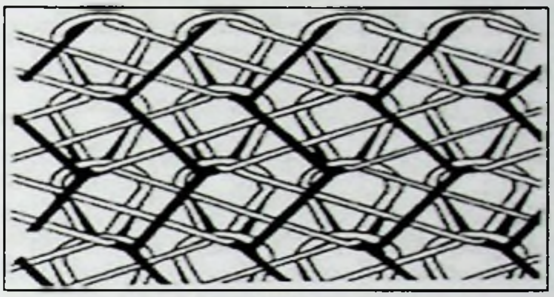

Figure 2.4: Two guide bar warp knitted fabric
Source: Raz.S. 1987

The fabrics which are produced by use of two guide bars are having a good stability and give a much wider pattern scope. Many different effects could be achieved by altering the lapping movements and these effects may be increased still further by the use of, mixing different coloured yarns, linear densities or using different yarn types, such as yarns with different dyeing characteristics, textured yarns etc (Aanad, 2000).

2.2.4 Technical face & back of the fabric

The technical back of the warp knitted fabric could be identified by the underlaps which float on the technical back of the fabric. Whereas the surface which shows the loop structure or an overlap is the face side of the fabric (Raz.S, 1987).

2.2.5 Locknit Fabric

(Raz.S, 1987) Figure 2.5 shows a two bar structure known as Locknit. In this fabric one set of yarn shogs between two adjacent needles, while the other set shogs a larger traverse of two needle spaces. Because of that Locknit will give a softer touch and higher elasticity due to the free-floating longer underlaps. These free floating under laps are superimposed on the technical back of the fabric and it enhances the fabric luster of the technical back.

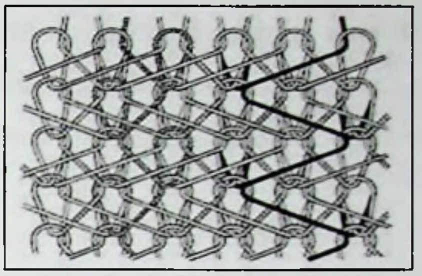

Figure 2.5: Locknit loop structure

Source: Raz.S. 1987

Further Dr. S. Raz mentioned in his book on warp knitting production, the locknit construction tends to contract width direction on leaving the knitting machine, so that its final width of the greige fabric will be 2/3 of the needle bar width. Just after leaving from the machine, fabric is named as greige. The amount of shrinkage of the greige material depends on knitting condition, yarn type and yarn tension. Locknit fabrics were traditionally produced on 28 gauge machine. The fabrics which were produced on 32 to 40 gauges had been popular and it is most suitable for ladies lingerie (Raz.S, 1987).

When the lapping movements of two guide bars are interchange, the properties of the resultant fabric called reverse Locknit are completely changed (Aanad, 2000).The short underlaps will now appear on the back of the fabric and will trap in the longer ones to give a more stable and stiff structure with far less width shrinkage from the needles than ordinary Locknit. The length of underlaps of the back guide bar may be further reduced to give even greater stability and opacity with practically no width shrinkage from the needles.

2.2.6 Fabric geometry of warp knitted structure

(Raz.S, 1987) stated that the tightness factor of a knitted fabric is determined by the yarn consumption of two guide bars. Further (Aanad, 2000) has defined the tightness factor of a knitted fabric is the ratio of the fabric area covered by the yarn to the total fabric area. It is a key factor to determine fabric characteristics and it influences dimensions such as the length, width, and thickness and many other fabric characteristics such as area density, opacity, abrasion resistance, modulus, and strength and fabric shrinkage (Aanad, 2000).

It is very useful parameter to measure of looseness or tightness of the structure. If the tightness factor of a knitted fabric is defined by K, the tightness factor of a single-guide bar fabric is defined as in Equation $K = \sqrt{tex}/l$ ((Aanad, 2000))

Where l is the stitch length, measured in millimetres and tex is the yarn linear density, then the tightness factor of a two-guide bar, full-set fabric is given by following equation.

$$K = \sqrt{tex_f}/l_f + \sqrt{tex_b}/l_b$$

Where suffixes f and b refer to front and back guide bars and l is the stitch length equal to (run-in/rack)/480 and is measured in millimetres. If the same tex is employed in both then

$$K = \sqrt{tex}\left(\frac{1}{lf} + \frac{1}{lb}\right)$$

For most commercial two-guide bar full set fabrics $1 \leq K \leq 2$ with a mean tightness factor value of 1.5. Similarly the area density of a two-guide bar full- set fabric would be represented by the equation as Mass of the fabric = $S\ [(l_f \times T_f) + (l_b \times T_b)] \times 10^{-2}\ gm^{-2}$

Where, S is stitch density (cm^{-2}) or (cpcm x wpcm), l is the stitch length (mm) and T is the yarn tex

suffixes f and b refer to the front and back guide bars. If the same tex is used in both guide bars then the above equation can be written as equation

Mass of the fabric = $S \times T \times 10^{-2}(l_f + l_b)\ g/m^{-2}$ or

= $S \times T \times 10^{-2}$ (total run-in /480) g/m^{-2}(Aanad, 2000)

If the stitch density, that is, the number of loops cm-2, stitch length in millimetres of the individual guide bars and tex of yarns employed in individual beams are known, the fabric area density can be readily obtained using the above equation in any fabric state, that is, on the machine, dry relaxed or fully relaxed.

2.2.7 Fabric quality

Raz.S, (1987) mentioned in his book that the quality of the warp knitted fabric is determined by the yarn consumption. Therefore properties of warp knitted fabrics are mainly determined by structure which is characterized by the form and size of loops. In warp knitting all the yarn ends threaded through the guides of one guide bar and knit the same construction. The yarn consumption of each guide bar is called run –in and is measured as the length of each yarn knitted into the fabric during 480 knitting cycles.

Aanad,(2000) investigated that the run –in per rack is the main parameter controlling the quality and properties of a given structure. In two-guide bar fabrics, the run-in per rack for each guide bar may be the same or different, it depends upon the fabric structure. Aanad, (2000) further stated that run-in may be altered in two different ways, first by altering the total run-in of the bars, and second by altering the ratio or difference between the bars. Altering the total run-in will affect the finished number of courses per centimetre and hence the area density of the fabric, the stability and the cover, but not the general shape of the loop. Altering the difference of run-in between the two guide bars will change the balance of the fabric, affect the inclination of the loops and, because it puts more or less strain on the individual yarns, as a result of that it changes the strength. Fabric take-up on the machine is adjusted to attain trouble-free knitting and also to affect ease of finishing.

2.2.8 Parameters that effect to quality of the fabric

Length of underlap

The length of the underlap is defined by length of the shogging movement as determined by the number of needle space moved by a guide/guides bar. The longer the underlap the more it lies width wise in the fabric. Therefore it increases the widthwise stability. In the same way when the underlap is shorter, it increases the lengthwise stability. The length of underlap affects the fabric weight as well. While knitting with long underlaps, more yarn is fed into the fabric. The underlap crosses and covers more wales on its way with the result that the fabric becomes heavier, thicker and denser (Raz.S, 1987).

Keyzer, (2011) studied the properties of the fabrics knitted with open and closed loops. The properties of the knitted fabric are different for open and closed loops, open loops have all the properties desired in the fabric except for the elastic strain recovery. As the fabric extensibility is considered to be an important factor, open loops are preferred. However, open loop movements are more difficult to form, except for the open pillar stitch. The successful formation of open loops strongly depends on the tension of the warp yarns. If the applied tension is incorrect, the loop can slip off the needle during the next knitting cycle.

According to (Raz.S, 1987) the fabric which is knitted with open loops tend to be flimsy, and lack stability because the yarns do not cross at the bottom. Whereas closed loops are those that do cross at the bottom make a more stable fabric. Table 2.1 is presents how properties of the knitted fabric are different for open and closed loops (Keyzer, 2011).

Table 2.1: Properties of Fabrics which are having closed & open loops

Fabric property	**Open loop**	**Closed loop**	**Desired in**
Elastic strain recovery	Lower	Higher	Higher
Extensibility	Lower	Higher	Lower
Edge curling	Lower	Higher	Lower
Lustre	Higher	Lower	Higher
Wear on knitting element:	Lower	Higher	Lower

Source;(Keyzer, 2011)

2.3 Introduction to elastane yarn

(Kirket al. 1966) studied the apparel fabrics which was produced by elastane yarn and derived the following relationship: body skin strain = garment fit + garment slip + fabric stretch. Main finding of this study was higher stretch with lower power was always preferred by the consumer, wear's preference for stretched fabric were established at a 25% to 45% stretch range, it depends on the end use, the direction of stretch relative to the body has an important effect on comfort.

Elastic fabrics are an important route to achieve comfort by freedom of movement for body fitted with sports and outerwear. This type of fabric enables freedom of body movement by reducing the fabric resistance to body stretch (M.Senthilkumar et al, 2011). Drastic differences between skin and fabric movements result in restrictions of movement to the wearer. Elastane fibre, yarn and fabric provide the necessary elasticity to a garment (J.Voyce et al. 2005).

LYCRA is a registered trademark used for DUPONT elastane fibres. Spandex is a generic term used to designate elastomeric fibres which are having an greater extension at break (J.Voyce et al, 2005) LYCRA® by US and Canada. Elastane could be defined as a manmade fibre in which the fibre-forming substance is a synthetic chain polymer containing at least 85% segmented polyurethane. Elastane has a property which does not found in nature, the most important property is having an extraordinary elasticity. Though the elastomeric fibres based on block copolymers were developed and patented by DuPont in 1950, it was only in 1962 that their first commercial fibre was marketed as "Lycra". The polymer for Lycra was made by reacting polyglycol (tetra-methylene ether) with an excess of diphenylmethanediisocyanate (MDI) to give a capped glycol with isocyanate end groups, which was then 'chain extended' with hydrazine to form the segmented elastomer. Solvent (dimethyl formamide) solutions were then dry and wet spun into spandex fibres. DuPont scientist Joseph C. Shivers invented DuPont's spandex fiber in1959 after a decade of research (Textilesite: what is lycra, Lycra yarn and its properties, 2012).

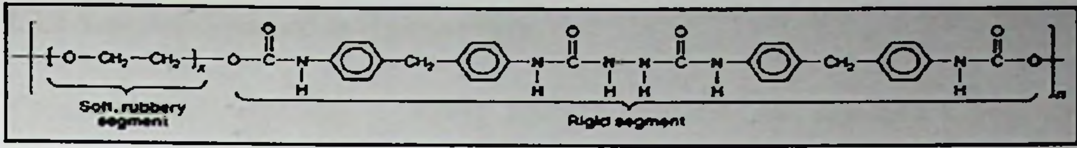

Figure 2.6: Chemical structure of Lycra polymer

Source: Hearle.J.W.S. 2009: .Page 328

LYCRA can be stretched four to seven times its initial length, yet springs back to it's original length once tension is released. While LYCRA® appears to be a single continuous thread, it is in reality a bundle of tiny filaments. Testing for elastane yarn and fabric is not similar to that used for hard yarn and its fabric. Because the slight variation in spandex yarn tension affects its properties (J.Voyce et al, 2005)

2.3.1 Characteristics of elastane fibre

It can be stretched repeatedly and still recover to very near its original length and shape generally stretched more than 500% without breaking. When compare with natural rubber, spandex is more strong, durable and has higher retractive force than rubber. It is lightweight, smooth, soft, dyeable and heat-settable. It facilitates transforming puckered fabrics into flat fabrics, or flat fabrics into permanent rounded shapes. The garment made out of fabric which consists of elastane yarn provides a combination of comfort and fit by preventing bagging and sagging. Further it resists to deterioration by body oils, perspiration, and lotions or detergents (Textilesite: what is lycra, Lycra yarn and its properties, 2012). Lycra is never used alone, it is always combined with another fiber (or fibers), natural or man-made. Fabrics enhanced with LYCRA® retain the appearance of the majority fibre.

The type of fabric and it's end use determine the amount and type of LYCRA® required to ensure optimum performance and aesthetics. As little as 2 percent LYCRA® is enough to improve a fabric's movement, drape and shape retention, while fabrics for high-performance garments such as swimwear and active sportswear may contain as much as 20-30 percent LYCRA®(J.Voyce et al, 2005).

2.3.2 New developments in elastane yarn

Hyosung, (2014) Hyosung, a leading elastane producer, has launched a new eco-friendly elastane, it is named as 'creora easy scour', designed to reduce water usage. The new product is also said to enhance the colour appearance of fabric. "We developed this technology using our proprietary finish to meet the needs of mills who are using finer gauge knitting and finer yarns for more delicate fabrics," explained President CH Kim. It has been developed for heat settings at lower temperatures and it prevents heat damage and staining when blended with heat sensitive materials as well as providing superior dimensional stability and touch to garments. It also increases the heat setting speed, thus increasing overall with heat-sensitive materials as well as providing superior productivity. This is an eco-friendly material that reduces consumption of fossil fuels and CO_2 emissions due to its low-energy processing. Following is the added characteristics of this new development yarn15~20°C down in heat setting processes vs. regular spandex

- Energy savings from low-temperature settings
- High productivity
- Yellowing from high temperatures prevented, offering the brightest, crisp whites
- Superior dimensional stability with minimal curling
- Improved fabric hand through low-temperature processing
- Enhanced moldability of bras
- Fading of PET materials prevented (higher color fastness)
- Chlorine-resistance

End Uses

- Intimate apparel, active wear, denim and other garments
- Heat-sensitive materials (e.g. Nylon, Cotton, Rayon, Modal, Tencel, Wool, Silk)
- High density, lightweight, thin Nylon, PET fabrics

2.4 Introduction to nylon filament yarn

Two types of chemical reactions are used when producing synthetic organic fibres such as poly-addition and poly-condensation. Poly-addition uses the reactivity at some double bonds in the monomer. The double bonds are dissolved when the monomer units are added forming single bonds, thus forming a polymer chain. PP, PE and PVC are examples of poly-addition polymers. Nylon 6.6 is produced from the poly-condensation of 1,6diaminohexane, the traditional name of which is hexamethylenediamine and hexandioic acid which is often called adipic acid (Richards.A.F., 2005).

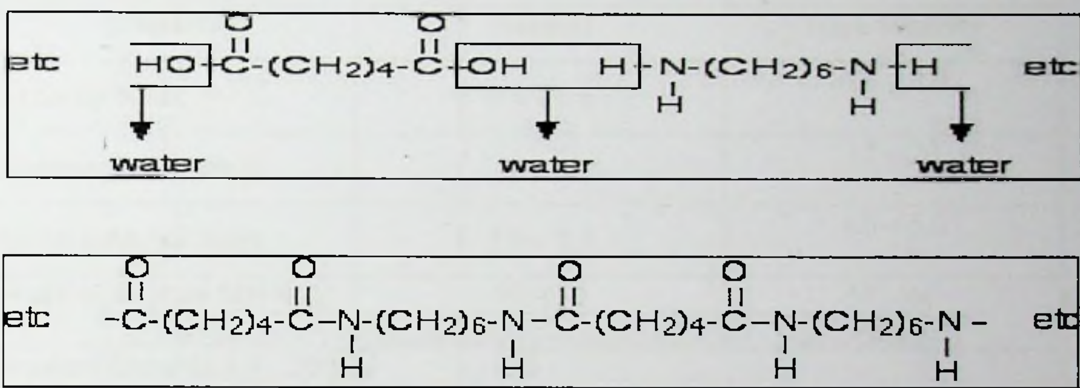

Figure 2.7: Formation of Nylon 6.6

Source: (Richards.A.F., 2005).

2.4.1 Tensile properties of Nylon 6.6

The tensile properties indicate the responses of the fibre to forces and deformations. They are vital in determining the suitability of a fibre for a particular application and in comparing it with other fibres. Properties of a textile structure depend on the fibre type which is used to manufacture the textile structure and the way in which the fibres are assembled into a yarn or fabric. The tensile properties of nylon and other fibres are most depend on the polymer, relative molecular mass, extrusion speed, draw ratio and the thermal history of the fibre.

When a force is applied to nylon fibre, it will become elongated. The extent of the elongation will depend on the linear density of the fibre or yarn. Nylon is often thought to be a hydrophobic fibre. In practice it is significantly hydrophilic and can absorb some water within the structure. Water is able to penetrate to the amorphous regions and hydrogen bond to the amide groups. Water is a good plasticizer for nylon and it increases the mobility of the molecular chains reducing the tenacity and modulus while increasing the extension at break. The effect of the water is not as great as with cellulosic fibres, but it is sufficient for its effects to significantly influence tensile tests (Richards.A.F, 2005).

Table 2.2 Main tensile properties of Nylon 6.6

Properties	**Normal**	**High tenacity**
Tenacity N/tex	0.4 – 0.6	0.6 – 0.9
Breaking extension%	20 – 30	15 – 20
Initial modulus N/tex	2.0 – 3.5	4.0 – 5.0
Work of Rupture MN/tex	60 – 70	50 – 60

Source (Richards.A.F., 2005).

Table 2.3: values for the yield strain and elastic recovery of nylon 6.6

Yield strain%	**Elastic recovery%**		
	1% extension	**5% extension**	**10% extension**
16	90	89	89

Source: (Richards.A.F., 2005).

2.4.2 Thermal properties of Nylon 6.6

The thermal properties of nylon polymer and fibre is of fundamental importance in determining the conditions of manufacture and conversion into fabric. The presence of the amide linkages in the molecular chains has a considerable effect on the thermal properties. The presence of the amide groups raises the melting point and the relationship between the number of amide links and the melting point is shown in table 2.4

Table 2.4: Thermal properties of Nylon 6.6 at zero relative humidity

Property	Temperature ^{0}C
Melting point	215 - 220
Zero strength	220
Maximum setting temperature	190
Softening point	170
Maximum ironing temperature	150
Optimum setting temperature (steam)	128
Glass transition temperature	40 - 50

Source: (Richards.A.F, 2005).

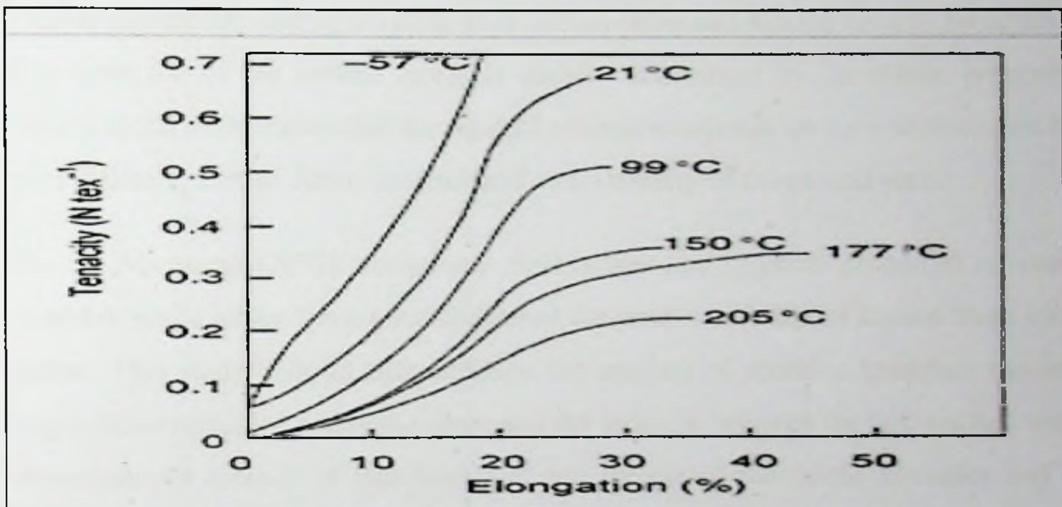

Figure 2.8: Effect of temperature on the tensile properties of Nylon 6.6

Source: (Richards.A.F., 2005).

2.5 Research review

Saber Ben Abdessalem*et al*,(2009) studied the relation between elastane yarn consumption and fabric dimensional and elastic behavior. Five samples of cotton/elastane plated single jersey fabrics were used in this study. Fabrics were knitted at varied elastane feeder speeds, while the ground yarn (cotton) consumption was kept constant speed at 31 cm/10 needles. It was observed that the amount of elastane content of the fabric has a significant effect on dimensional and elastic properties of cotton/elastane plated single jersey knitted fabric. It was explained by the fact that the decrease of elastane consumption involves an increase of elastane tension.

The tension inside the elastomeric yarn makes stitch wales closer to each other. Consequently, the fabric width is reduced and stitch density which is expressed by fabric weight is increased. When the fabric weight decreases with the increase of elastane consumption, this phenomenon was linked to tension inside the elastomeric yarn. Ground yarn consumption is constant but stitch geometric configuration was modulated by the tension applied by the elastane plating yarn. It was concluded that knitted fabric area density is determined by both yarn and knitted fabric parameters. In order to keep the area density in accordance with the order specification, knitting process parameters such as elastane yarn consumption and tension have to be adjusted. The final use of the knitted fabric is usually determined by its elastic properties. Experimental study shows that the residual extension depends on yarn composition and yarn structure, knitted fabric structure and wales density of the ground yarn.

Bayazit Marmarali.(2003) studied the dimensional and physical properties of cotton /spandex single jersey fabrics and compared the results with fabrics knitted from 100% cotton. This study showed that although the amount of spandex increases the loop length value remained nearly the same and the space in between the courses and wales decreased. As a result of that thickness and weight of the fabric increases and air permeability, resistance to pilling and degree of spirality decrease of the single jersey fabric knitted with cotton/spandex.

Mukhopadhyay,(2003) studied the impact of lycra filament on extension and recovery characteristics of cotton knitted fabrics. In this study, four different samples are used; non lycra compacted, non lycra fully relaxed, Lycra compacted and Lycra fully relaxed fabrics. Result revealed that overall performance of Lycra blended fabric is better than that of non Lycra blended fabrics as resiliency, extension at peak load and immediate recovery.

Extension at peak load in the Lycra blended fabric was approximately three times higher than that of non Lycra fabrics in wale direction and two times higher in course direction. This was due to the presence of Lycra filaments in the fabric, assisting it to shrink in wales direction when comes off from the knitting machine. Subsequently, the courses per inch of the fabric increases, allowing more loops to contribute towards extension at peak load, particularly in wales direction. Further they stated that based on the data analysis, the Lycra blended fabrics also had higher, stitch length, the impact of which was also greater in course direction than that in wale direction, resulting in higher extension at peak load in course direction.

Further it has been observed that the fully relaxed fabric possesses higher extension than that of compacted fabrics. This was because higher number of courses per inch leading to the possibility of greater extension. Finally they have concluded that the fabric relaxation and setting treatment results in the reduction in magnitude of internal forces acting within the fabric. Consequently the internal frictional restraints within the fabric were reduced, this effect was found to be very important in relation to the bending behavior of fabrics where inter fibre frictional properties play an important role.

R.Sadek*et al*,(2012) studied the effect of Lycra extension increase percentage on the geometrical, physical and mechanical properties of plain single jersey knitted fabrics produced from cotton and Lycra yarn. Lycra percentage of the sample has been changed by changing knitting sequence of Lycra yarns. Lycra of the one sample were used in alternating courses (half plating) and feed the yarn at five different extensions. Second sample knitted with the Lycra in every courses (full plating) and selected the same extensions values.

This study revealed that there was a relationship between Lycra content and extension % of the Lycra yarn of the fabric and fabric parameters such as course density, wale density, fabric thickness, air permeability and the initial elasticity modulus. When the Lycra yarn was in half plating, the fabric which was having optimum 82% Lycra extension showed positive impact on the course and wale density, fabric thickness and air permeability of the fabric. But it shows negative impact on the abrasion resistance of the single jersey fabric.

The fabric which was having full plating of Lycra yarn and 103% - 232% optimum Lycra extension showed better results for the initial elasticity modulus and the abrasion resistance. It improves the abrasion resistance property by 15% of the fabric and decreased by 69% the initial elasticity modulus. Finally it was concluded that the Lycra percentage (either half or full) and the extension percentage of the Lycra yarn could be selected according to the required end use of the knitted fabrics.

Serkan Tezal *et al,*(2008) studied the effects of different brand of spandex yarn and tightness factor on dimensional properties such as courses per cm, wales per cm, stitches per cm^2 , fabric weight, thickness and physical properties such as air permeability and bursting strength of cotton/spandex single jersey fabrics.

Methodology they have followed was, four different spandex brands were used in order to investigate the effects of spandex brands on the physical and dimensional properties of cotton and spandex single jersey fabrics. In order to examine effects of the tightness factor of cotton and spandex yarns, fabric samples were knitted by selecting three different loop lengths for each cotton and spandex yarn to get tight, medium and loose cotton/spandex single jersey fabrics. First sample was knitted with minimum cotton yarn loop length value (cotton – tight) and maximum spandex yarn loop length value (spandex – loose). Second sample was knitted with maximum cotton yarn loop length value (cotton – loose) and minimum spandex yarn loop length value (spandex – tight). Third sample was knitted with the medium yarn loop lengths were determined by calculating the average of the maximum and minimum yarn loop lengths.

Spandex brands had a highly significant influence on weight, cotton yarn loop length, spandex yarn loop length, course and wale per cm, stitches per cm^2, thickness and air permeability of the fabrics. The fabric knitted with spandex yarns which feeds under constant draw ratio with the highest tension values gave the highest weight, courses per cm, stitches per cm, thickness and the lowest air permeability and bursting strength values. Spandex yarns which had the similar elongation% values affect the wales per cm values in a similar trend.

Tightness factor value of a single jersey fabric knitted with cotton and spandex is also have great impact on weight, course and wale per cm, stitches per cm^2, thickness and air permeability of the fabric. Shorter loop length values of cotton and spandex yarns gave the highest weight, courses and wales per cm and the lowest air permeability.

Study revealed that the thickness of a fabric increased as the spandex yarn loop length decreased. Although the tightness factor of cotton yarn has the significant influenced on bursting strength, impact of spandex yarn on bursting strength was not so significant. The bursting strength of the fabric increased as the cotton yarn loop length decreased. Finally study confirmed that the weight, thickness and stitch densities of cotton/spandex fabrics were higher than they were in 100% cotton fabrics except air permeability value.

Alenka Pavko Cuden*et al*, (2013) investigated the impact of material, knitted structure and relaxation process parameters on loop length. In order to carry out the investigation,32 different knitted samples were prepared combining the two fibre types, four yarn structures, two density levels and two relaxation procedures. It was observed that the knitted fabric density had a direct impact on the course density of the knitted structure and consequently influences the loop length. Fibre type, yarn structure, knitted fabric density level and the relaxation process all had a statistically significant effect on loop length. The fibre type influences the loop length only in the case of elasticized knitted fabrics. Elastane addition does not significantly influence the loop length of fabrics knitted using the same machine cam setting and relaxed by the same process.

M.Senthilkumar*et al,*(2012) analyzed the effect of spandex input tension, spandex linear density and cotton yarn loop length on dynamic work recover of cotton/spandex single jersey knitted fabric. Further the effect of different processing stages such as relaxation, heat setting, bleaching and compacting on dynamic work recovery of cotton/spandex ingle jersey knitted fabric were analyzed. Effect of different stages of processing on dynamic work recovery of the fabric has significant influence. The effect of spandex input tension on dynamic work recovery of the fabric has been significant in wale direction and it has no influence on course direction. But effect of cotton yarn loop length on course direction is significant.

Effect of spandex linear density on dynamic work recovery of the fabric has been significant at both wale and course directions. Spandex input tension, spandex linear density and cotton yarn loop length are significantly influenced the extension levels on dynamic work recovery of the cotton/spandex fabric.

Mir Reza Taheri Otaghsara*et al*, (2009) studied that tensile property and fatigue behaviour of warp knitted fabrics. The fabric structures were Tricot, Locknit, Reverse Locknit, three needle Satin, four needle satin, three needle sharkskin and four needle Sharkskin. Each of these structures was knitted at three different course densities (15, 20 and 25 courses per centimeter).

The result was concluded that course density of a warp knitted fabrics has an influence on the tensile and fatigue properties of warp knitted fabrics. Further the tensile behavior of the fabric could be controlled by means of the length of underlap and the space available for yarn movement in the fabric structure. Further revealed that length of back guide bar under lap has a significant influence on tenacity of warp knitted fabrics rather than the length of underlap made by front guide bar.

Although the tenacity was increased by increasing the course density, no considerable difference was observed for the breaking stress due to courses per cm. He has defined the term "cyclically stablised stress". Repeated straining causes stress relaxation in warp knitted fabrics and the maximum stress in each cycle degreased as the number of cycles increased, and the maximum stress in the given amplitude of extension reached a constant amount, this phenomenon is known as cyclically stabilized stress. This research revealed that cyclically stabilized stress of the fabrics was increased by increasing length of underlap. But there is a significance influence on length of back guide bar under lap rather than the length of front guide bar under lap. There is no distinguishable trend between the cyclic stabilized stress and the courses per cm of the fabric

A.A.Jeddi*et al*, (2004) studied on "Investigation of fatigue behaviour of warp knitted fabrics under cyclic tension". In this investigation, found out influence of number of loading cycles and stork on mechanical properties of polyester filament yarn and warp knitted fabric structures. Fabric structures were Tricot, Locknit, Reverse Locknit, Satin and Sharkskin. Study was revealed that the elasticity behavior of a warp knitted fabric is depended on the amplitude of slippage and movement of the yarns inside the fabric structure according to the applied tensile tension on the fabric. When tensile load was applied on to the filament yarn, it's strain depends on the mobility of its molecules on each other. But in fabric this phenomenon was depended on purely a structural property of the fabric. There was no effect on the nature of the yarn used in the fabric.

So elasticity of warp knitted fabric depends on two factors. One was the space available in between overlaps and front guide bar underlap in the fabric. If this space was sufficiently large, the back guide bar underlap can move easily. The other factor was length of underlap. When the length of the underlap was increased, the strain value in the course direction could be decreased while in the wale direction it can be increased. Increase in front guide bar underlap, and simultaneously the increase in the underlap angle to the tensile direction, fabric deformation was increased. This experiment inferred that, longer underlap in the front guide bar gave a larger space in the fabric structure for yarn movement, and causes more fabric deformation than the fabric with longer underlap in the back guide bar. The main reason for this phenomenon was the presence of sufficient space for easier yarn slippage and movement inside of fabric structure. This was revealed when subjected to higher existing space available for yarn movement had the great impact on elasticity behavior of warp knitted fabric rather than the length of underlap. Finally it has revealed that the resistance of the yarn to cyclic loading was increased, in increasing cycle number, the residual yarn extension and yarn modulus. But the breaking extension% was decreased. The yarn breaking tenacity, the yarn modulus and the residual yarn extension of fatigued yarns were increased with the in stroke, while the yarn breaking extension % is decreased.

CHAPTER 3: METHODOLOGY

3.1 Methodology

To achieve the set objectives of the study the following research methodologies are followed.

1. Study the literature relevant to the study
2. Produce four fabric samples selecting four different run-in in order to achieve different percentage of elastane and nylon in the fabrics
3. Carry out experiments on fabric width, weight, courses and wales, bursting strength and stretch and recovery of the samples
4. Analysis of the test results

3.2 Preparation of Materials

3.2.1 Yarn Details

Following yarns were used for the preparation of knitted test samples.

Table 3.1 – Details of the yarn used for knitting the fabrics

Yarn Type	Yarn Lable	Yarn count	Tenacity CN/Tex	Elongation%	Extension
Elastane (Spandex)	44dtex	44dtex	≥4.8	45.9	65%
Nylon	44D/10F/D	44denier	40	40	-

3.2.2 Sample preparation

Table 3.2 shows the machine specifications of the warp knitting machine that was used to knit samples for the experiments.

Table 3.2 - Details of the machine used for knitting the fabrics

Machine Type	**Machine Gauge**	**Total no of needles**	**No of guide bars**
Tricot warp knitting	32	4044	4

Two guide bars were fully threaded and nylon and spandex yarns were fed from two separate warp beams. The yarn tension in both guide bars is properly balanced. Closed lap lapping movement was used to produce the samples. nylon yarns were threaded from a guide bar at a front side of the knitting machine and shogged one needle space and elsatane yarns were threaded from a guide bar at the backside of the machine and shogged 1 and 1 lapping movement. The chain notations of the two guide bars are as Front Bar 2-3/1-0 – nylon yarn and Back Bar 1-0/1-2 – Lycra yarn.

The four knitted samples were produced with different run-in ratios in order to study the effect of Nylon and elastane contents of locknit warp knitted fabrics on dimensional and physical properties such as GSM (g/m2), fabric width, wales and courses densities and stretch and recovery behavior.

Samples were produced keeping constant run-in of nylon yarn coming through the front guide bar and changing the run-in length of elastane yarn. Then elastane yarn run-in was kept constant. Samples which have been produced with different run-in ratios were coded as T1G, T2G, T3G and T4G. Letter G denotes the greige status. Table 3.3 shows the run - in ratios of two guide bars and the sample codes.

Table 3.3 – Coding methods of the greige fabrics

Sample code	**Front bar Run-in (mm) nylon**	**Back bar Run-in (mm) elastane**	**Fibre composition**	
			Nylon%	**Elastane%**
Constant Nylon run-in				
T1G	1400	550	80.2	19.8
T2G	1400	485	80	20
Constant Nylon run-in length				
T3G	1330	580	79.8	20.2
T4G	1330	550	80.89	19.11
Constant elastane run-in				
T1G	1400	550	80.2	19.8
T4G	1330	550	80.89	19.11

Fabric finishing process

Length of fifty meters of greige fabric were taken from each sample for the final setting of the greige fabric. Fifty meters of greige samples were passsed through the stenter machine in stretched form in the width direction under 120^0c. Stretched percentage is decided by the ultimate quality of the fabric. The samples T1G, T2G and T3G were stretched by 24% and the sample T4G stretched by 20%. These finished samples were coded as T1F, T2F, T3F and T4F. Letter F denotes the finished status.

3.2.3 Testing of greige and finished samples

Conditioning of samples

All physical tests were carried out at standard testing conditions maintaining temperature and relative humidity according to SLS 1250:2003. 65% +/- 4% relative humidity and standard temperature – 21+/- 1^0 C (70 +/- 2^0 F). The samples were conditioned for 24 hrs in the condition room in order to reach the samples to relax state and standard moisture level.

Fabric width test

"Test method -ASTM-D -3774 – Width of textile fabric" was used to determine the fabric width of greige sample. After the relaxation period was over, the measurement is made in three different places while the fabric lying flat under no tension or wrinkles. Three measurements of the fabric width were taken first, middle and end of the fabric roll according to the test method and finally average value was calculated for each sample. Fabric width is the distance from one selvedge to the other and unit will be in meters.

Fabric weight in g/m^2 test

"Test method-ASTM – D- 3776 – Mass per unit area" was used to determine the fabric weight in greige and finished stages. Five specimens were cut from each fabric sample in different places according the test method and calculated the average value of the five reading. Fabric weight of each sample was expressed as a g/m^2 value. Area of the specimen has known dimensions which has taken by a cutting device; it is 10000 mm^2. When specimen was cutting, it was avoided taking specimen from the fabric selvedge or close to the ends of a fabric piece. Figure 3.1 shows the sample preparation for the Test method-ASTM – D- 3776 – Mass per unit area.

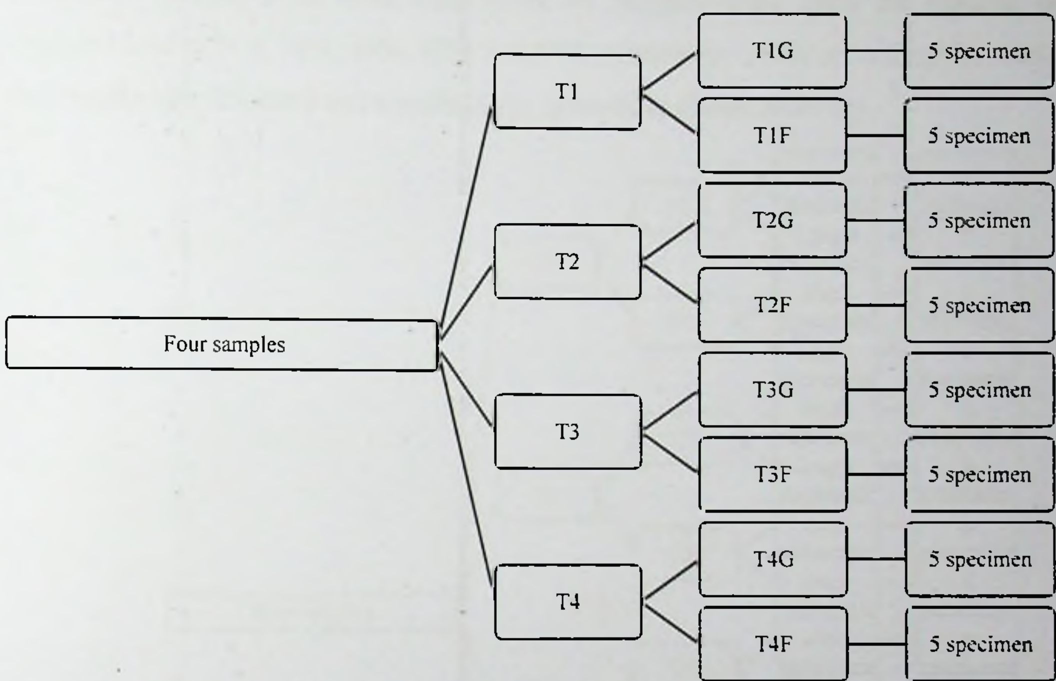

Fig 3.1: sample preparation method for test method ASTM–D-3776–Mass per unit area.

Determination of wales & courses density

"The ASTM – D- 3887- wales & courses test" method was used to determine the courses and wales per inch of greige and finished samples. Reading was taken for the five different places on every sample with a magnifying glass. After taking the five readings, the average values were calculated for each sample.

Determination of Stretch and recovery

"Test method - LTD - 03 – stretch fabrics – power and recovery" was used to determine the stretch and recovery property of the greige and finished fabric. Five test specimens were cut from length and width direction of each sample according to the test methods and test was carried out using Instron Tensile tester. Specimen preparation were shown in figure 3.2.The samples were subjected to elongation with gauge length 127mm for 76.2mm x 127mm with cross head speed of 50.8mm//min. Then the reading was recorded load in N at 20%, 40%, 60% and 80% extensions. After recording the reading the sample was unloaded and measured for immediate elastic recovery.

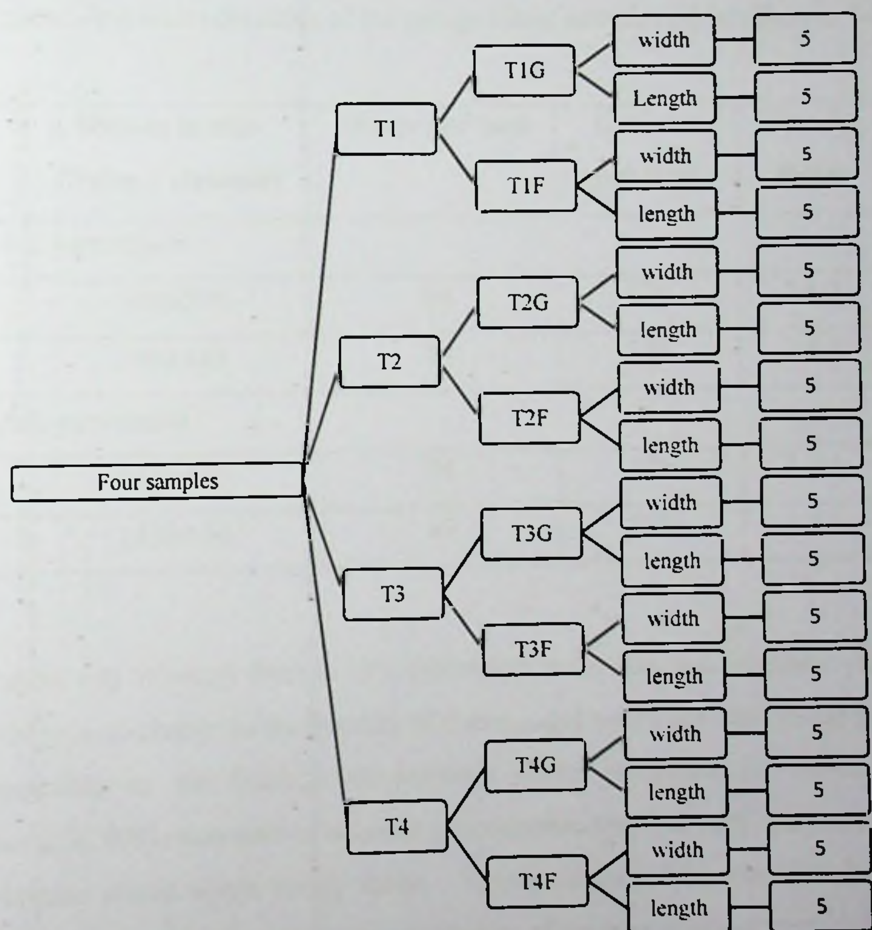

Fig 3.2: Sample preparation method for test method LTD 3-Stretch and recovery.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Analysis of the properties of greige fabric samples

4.1.1Courses and wales densities of greige fabric samples

The samples which are having varied run-in of elastane yarn and constant run-in of Nylon yarn were observed for courses and wales per inch for the purpose of investigating the dimensional properties of the fabrics with different contents of elastane yarn.

Table 4.1- Courses and wales densities of the greige fabric samples Nylon Run-in 1400 and 1330

Sample	Run-in in mm (Nylon : elastane)	Wales per inch	Courses per inch	Run-in Ratio
Constant Nylon yarn run-in				
T1G	1400:550	84	128	2.5:1
T2G	1400:485	84	128	2.8:1
Constant Nylon yarn run-in				
T3G	1330:580	84	126	2.3:1
T4G	1330:550	84	124	2.4:1

The results show that although there is 13% difference in the run-in of elastane yarn in the fabrics, there is no change in the number of courses and wales per inch in the greige fabric. According to the findings of research paper presented by Saber Ben Abdsssalem*et al.* (2009) on impact of elastane on extension and recovery characteristics of Cotton/elastane plated single jersey fabric. It was explained by the fact that the decrease of elastane consumption involves an increase of tension elastane yarn.

The sample T2G fabric was knitted changing the elastane run-in from 550 mm to485mm, while the Nylon yarn run-in was kept constant at run-in of 1400mm. It builds the tension inside the elastain yarn in T2G. It leads to remain the number of courses and wales per inch without changing of the greige fabric.

When compare samples T3G and T4G, there is a 5% increase in the run-in length of elastane from the samples T4G (550mm) to T3G (580mm), while the Nylon yarn run-in was kept constant at 1330mm.It makes the elastomeric yarn in more relax position. Decreases of run-in of Nylon yarn leads to reduce length of overlap of the Nylon yarn as well. As a result of that lateral compression of stitches produced by Nylon is more. It shows in small change of 1.58% difference in the course density. There is no change in the wales density, when compare the course densities of T1G and T2G against the T3G and T4G, it reveals that the effect of Nylon run-in on course density is more when the changing percentage of run-in of Nylon is comparatively small and elastane is more. However, this need to be further studied for more conclusive finding.

Two samples knitted with constant elastane run-in in greige stage show the following results in wales and courses per inch.

Table 4.2- Course and wale densities of greige fabrics – elastane Run-in 550

Sample	**Run-in in mm (Nylon : elastane)**	**Wales per inch**	**Courses per inch**	**Run –in Ratio**
Constant – elastane yarn run-in				
T1G	1400:550	84	128	2.5:1
T4G	1330:550	84	124	2.4:1

When the run-in of nylon yarn increased by 5% from T4G (1330) sample to the T1G (1400). It increases the course density of the sample T1G.

According to the literature review, stitch geometric configuration was modulated by the tension applied by the elastane yarn. Here the elastane yarn run-in was not changed, but value of Nylon run-in has been increased by small percentage. Higher run-in of Nylon yarn increases the overlap produced by front guide bar threaded with Nylon yarn in sample T1G.

4.1.2Stretchability of the greige fabric samples in length direction

Table 4.3 shows the load values in N at 20% extension, when the samples are having different elastane run-in at constant run-in of Nylon. Code G_L denotes load at 20% extension in lengthwise direction of the greige sample. Letter L denotes the Length direction of the sample.

Table 4.3- Load at 20% extension of the greige samples in length direction – Nylon run-in 1400

Sample	Run-in in mm (Nylon : Elastane)	Load (N) at 20% extension	Stitch density /Inch	Run-in ratio	Tight ness factor
Constant - Nylon run-in					
T1G_L	1400:550	4.34	128 x 84	2.5:1	2.18
T2G_L	1400:485	5.08	128 x 84	2.8:1	2.37

When compare the two fabric samples T1G_L and T2G_L, where the run-in values of the Nylon yarn is 1400mm while the run-in of elastane yarn is 550mm and 485mm respectively. When the length of elastane yarn is increased by 13% from sample T2G to T1G sample, the load at 20% extension has decreased by 15%.

But the values of stitch densities (cpi & wpi) are the same, Tightness factor values of the sample T1G_L and T2G_L are different;2.18 and 2.37 respectively. This is due to the fact that low run in of elastane yarn increases the strain of the yarn and it increases the tightness factor value of the sample T2G_L. It contributes higher load at extension along the wale direction in sample T2G_L.

Table 4.4- Load at 20% extension of the greige samples in length direction - Nylon Run-in 1330

Sample	Run-in in mm (Nylon : elastane)	Load (N) at 20% extension	Stitch density /Inch	Run-in ratio	Tightness factor
Constant - Nylon run-in					
$T3G_L$	1330:580	2.70	126 x 84	2.3:1	2.15
$T4G_L$	1330:550	4.29	124 x 84	2.4:1	2.22

When compare the two fabric samples $T3G_L$ and $T4G_L$, where the run-in values of the Nylon yarn is 1330mm while the run-in of elastane yarn is 580mm and 550mm respectively. When the length of elastane yarn is increased by5% from sample T4G to T3Gsample, courses per inch was increased by 1.5%.It allows more loop to contribute towards extension at load particularly in the wale direction As a result of that the load at 20% extension of the sample $T3G_L$has decreased. It shows that there is an impact of elastane run-in on elongation behavior of length (course) direction of the fabric in greige stage.

Further the lowest value of load at 20% extension of the fabric $T3G_L$ is due to the larger run-in of elastane yarn leading to the smaller tightness factor value of the fabric and it increases the possibility of greater extension at smaller values of load. Further the sample $T2G_L$ shows the maximum load at 20% extension. Hence there is a significant effect of run- in ratio of Nylon and elastane on extension behavior of the fabric.

Table 4.5 shows the load values at 20% extension, while the samples are having different Nylon run-in length at constant run-in of elastane.

Table 4.5- Load at 20% extension of the greige samples in Length direction - elastane run-in 550

Sample	Run-in in mm (Nylon : elastane)	Load (N) at 20% extension	Stitch density /Inch	Run-in ratio	Tightness factor
Constant – elastane run-in					
T1G$_L$	1400:550	4.34	128 x 84	2.5:1	2.18
T4G$_L$	1330:550	4.29	124 x 84	2.4:1	2.22

When the Nylon run-in is changed by 5% without changing the run-in of elastane yarn, it increases the run-in ratio of the sample T1G$_L$.Hence load at 20% extension of the sampleT1G$_L$ is increased by a small percentage that is 1.15%.

When compare the load at extension values of T1G and T2G against the T3G and T4GWhereas the length of elastane yarn is increased by5% from sample T4G$_L$ to T3G$_L$, the load at 20% extension has increased by 37%.This shows that the effect of elastane contents of the sample is more on the load at extension values than the change in run-in of the Nylon yarn.

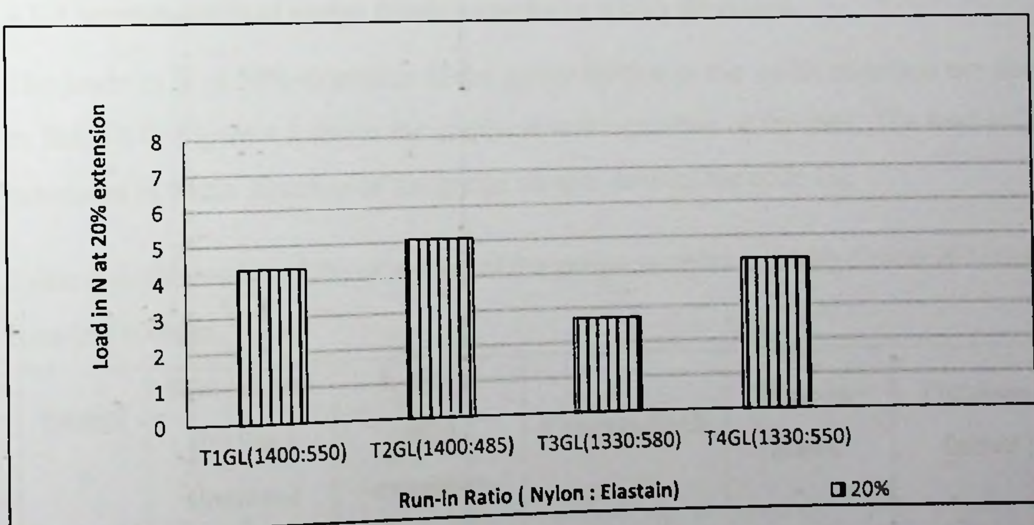

Figure 4.1: Load at 20% extension of the greige sample in Length direction

When the greige fabric samples were tested for 40%, 60% and 80% extension levels, required load in N were observed. Figure 4.2 represents the load at different extensions of greige fabrics when fabric was stretched in the length direction. The highest values of load at 20%, 40%, 60% and 80% extensions show the sample which is having the highest Run-in ratio, that is 2.8:1, whereas the lowest values of load at 20%, 40%, 60% and 80% extensions show the sample which is having the lowest Run-in ratio, that is 2.3:1.

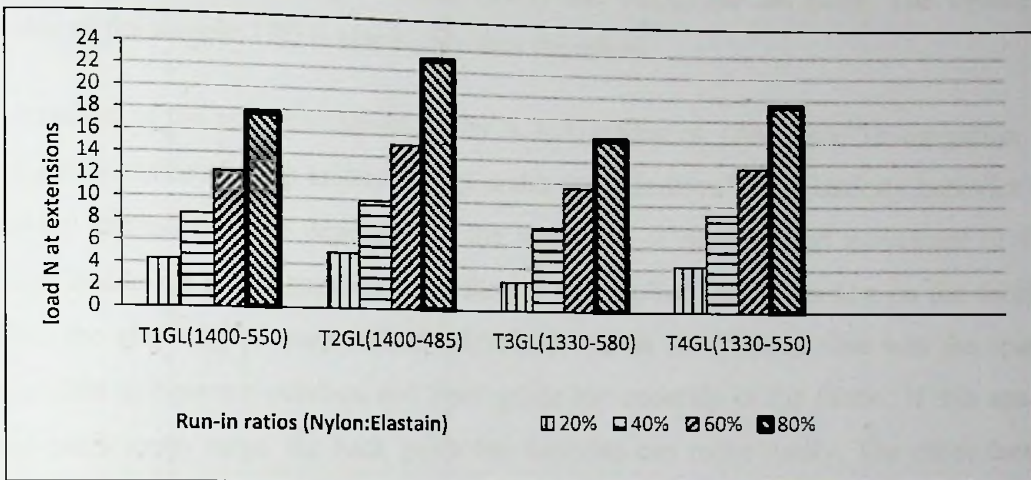

Figure 4.2: load at different extensions of greige fabrics - Length direction

4.1.3 Stretchabilityof greige fabric samples in width direction.

The loads in N at 20% extension of the greige fabrics in the width direction are shown in Table 4.6. Figure 4.3 shows the graphical representation of the data. The load at 20% extension in width direction of the greige sample denotes the code G_E.

Table 4.6-The loads at 20% extension of the greige samples in width direction-Nylon Run-in 1400mm

Sample	Run-in mm (Nylon : elastane)	Load at 20% extension	Courses/Inch	Run-in Ratio	Tightness factor
Constant Nylon yarn run-in					
$T1G_E$	1400:550	1.34	128	2.5:1	2.12
$T2G_E$	1400:485	0.88	128	2.8:1	2.37

The results show that the force required to stretch the fabric in the width direction is changed with the number of course per inch of the fabric. When the elastane yarn run-in is minimum, it shows the lowest load value in width direction. When consider the $T2G_E$ and $T1G_E$ samples, with increasing of elastane run-in which comes from back guide bar of the machine by 13%, the load at 20% extension has been increased by 52% in width direction. The elastane yarn of sample $T2G_E$ is in more stretch position, because the stitch density values of both samples ($T1G_E$ and $T2G_E$) are the same. The tightness factor of the sample T2G is also higher than the others.

According to the research carried out by A.A.A.Jeddi*et al*, (2004) on "Investigation of fatigue behavior of warp knitted fabrics under cyclic tension", the elasticity behavior of a warp knitted fabric is depended on the amplitude of slippage and movement of the yarns inside the fabric structure according to the applied tensile tension on the fabric. Thus the elasticity of warp knitted fabric depends on two factors. One was the space available in between overlaps and front guide bar underlap in the fabric. If this space was sufficiently large, the back guide bar underlap can move easily. The other factor was length of underlap. When the length of the underlap was increased, the strain value in the course direction could be decreased while in the wale direction it can be increased. The other factor is when increase in front guide bar underlap, and simultaneously the increase in the underlap angle to the tensile direction.

Table 4.7-The loads at 20% extension of the greige samples in width direction-Nylon Run-in 1330mm

Sample	Run-in mm (Nylon : elastane)	Load at 20% extension	Courses/Inch	Run-in Ratio	Tightness factor
Constant Nylon yarn run-in					
$T3G_E$	1330:580	1.55	126	2.3:1	2.15
$T4G_E$	1330:550	2.00	124	2.4:1	2.22

When compare the sample$T1G_E$&$T2G_E$ and$T3G_E$&$T4G_E$, two factors are contributed to reduce the load at extensions values in width direction. Those are the strain value in the course direction due to length of underlap in Nylon yarn and the increase in the underlap angle to the tensile direction due to shorter underlap of elastane yarn. Further results reveal that course density and elastic yarn contents of the fabric has a direct impact on the load at extension in width direction.

Table 4.8: Load at 20% extension - Width direction of the greige samples- elastane run-in 550mm

Sample	**Run-in (Nylon: elastane)**	**Load at 20% extension**	**Courses/Inch**	**Run-in Ratio**	**Tightness factor**
Constant – elastane yarn run-in					
$T1G_E$	1400:550	1.34	128	2.5:1	2.12
$T4G_E$	1330:550	2.00	124	2.4:1	2.22

When compare the sample$T1G_E$&$T4G_E$, elastane run-in was kept constant and Nylon yarn run-in has been decreased by 5%, Load at 20% extension has been increased by 33% of sample $T4G_E$, When reduce the runner length of Nylon yarn by 5% from 1400mm to 1330mm keeping the elastane runner length of the sample at the same value as 550mm. It shows that length of underlap of Nylon yarn has a considerable influence on load at extention in width direction rather than the length direction of the fabric.

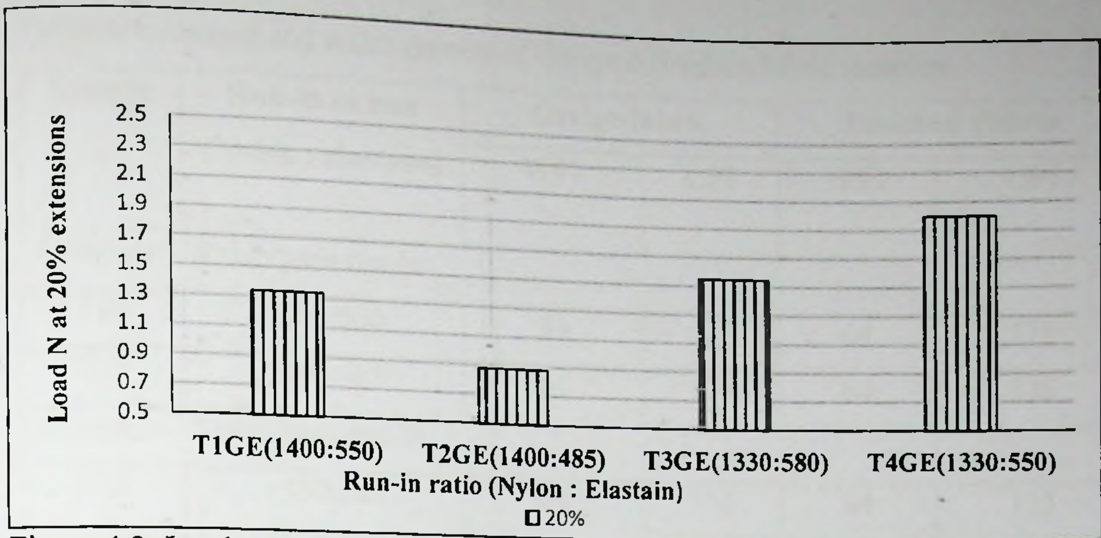

Figure 4.3: Load at 20% extension of greige sample in width direction

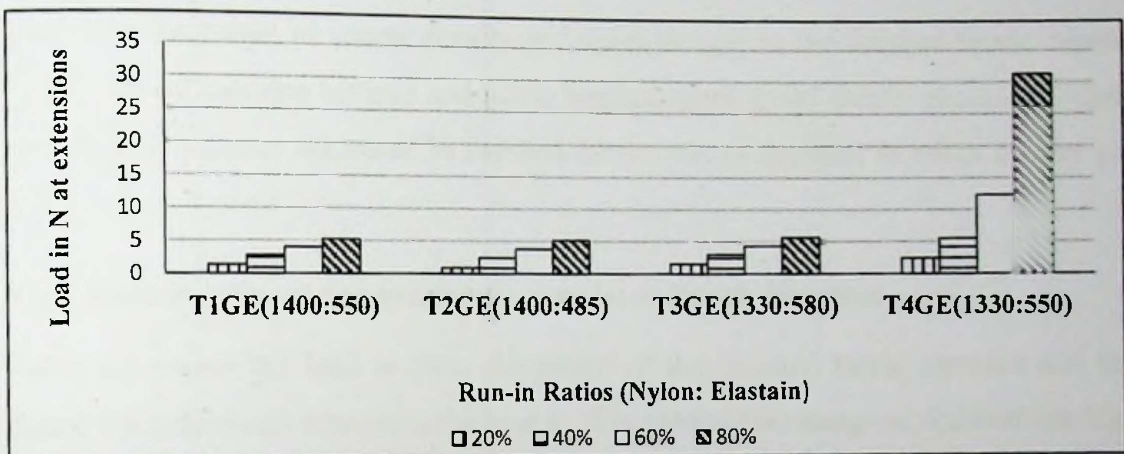

Figure 4.4- Load at different extensions of greige fabrics in width direction

4.2 Analysis of the properties of finished fabric

4.2.1 Courses and wales density of finished fabric samples

The table 4.9 shows the course and wales of greige and finished fabric samples. When the fabric was heat-set in width direction under stretched condition, the elastane yarn becomes finer due to stretch of the fabric widthwise. During final finishing process, the yarn friction is reduced and helps to bring the loops closer to each other. Although there is a significant change in the wales density (24%) due to stretching in the width direction, there is no significant change in the course density; 6% is the maximum change observed.

Table 4.9: courses and wales density of Greige &finished fabric samples

Sample	Run-in in mm (Nylon : elastane)	Greige fabric		Finished Fabric	
		WPI	CPI	WPI	CPI
Constant – Nylon yarn run-in					
T1F	1400:550	84	128	64	128
T2F	1400:485	84	128	64	136
Constant – Nylon yarn run-in					
T3F	1330:580	84	126	64	125
T4F	1330:550	84	124	68	126

However, the values of course density and wales density in the finished fabric depend on the stenter machine settings and fabric feeding speed to the stenter machine. Fabric weight g/m^2 value is decreased in finished fabrics due to decrease in stitch density per cm^2.

4.2.2 Stretchability of finished fabric samples in length direction

Table 4.5 shows the load at 20% elongation of the finished fabric samples and the figure 4.5 graphically represents the load at 20% tension percentage of finished fabrics.

Table 4.10- Load at 20% extension of finished fabric samples – Length direction – Nylon run-in 1400mm and 1330mm

Sample	Run-in in mm	Load at 20% extension	Run –in Ratio
Constant –Nylon yarn run-in			
$T1F_L$	1400-550	0.21	2.5:1
$T2F_L$	1400:485	0.05	2.4:1
Constant –Nylon yarn run-in			
$T3F_L$	1330:580	0.13	2.8:1
$T4F_L$	1330:550	0.70	2.3:1
Constant –elastane yarn run-in			
$T1F_L$	1400-550	0.21	2.5:1
$T4F_L$	1330:550	0.70	2.3:1

After the fabric samples have undergone the finishing treatment, Loads at 20%, 40%, 60% and 80% extensions has been reduced compare to the greige sample in length direction. It shows in graphically figure 4.6. During bleaching and dyeing process, the yarn friction has reduced and it helps to bring the stitches closer to each other. The water which use in these processes act as lubricating agent to reduce the friction.

Further it reduces the internal force in between the yarn of the fabric as well. So stitches of the fabric could be moved easily. Subsequently, the courses per inch of the fabric increases. It allows more loops to contribute towards extension at load particularly in wale direction. Further as explained in literature review the property of the elastic yarn and the nylon yarn has been changed during heat setting process. It affects the stretchability of the sample after finishing as well. Therefore values of load at extension is lower than the greige fabric. Before the fabric was finished, load at extension values of the samples are varied ($T2G_L>T1G_L>T4G_L>T3G_L$), after finishing values are varied($T4F_L>T1F_L>T3F_L>T2F_L$)

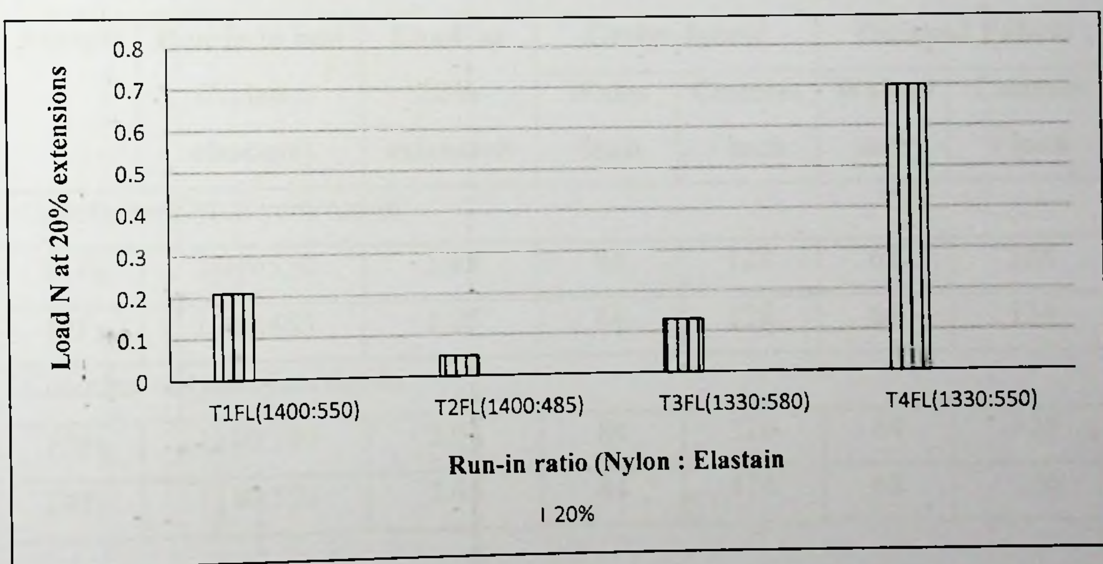

Figure 4.5- Load at 20% extension of finished fabric samples – Length direction

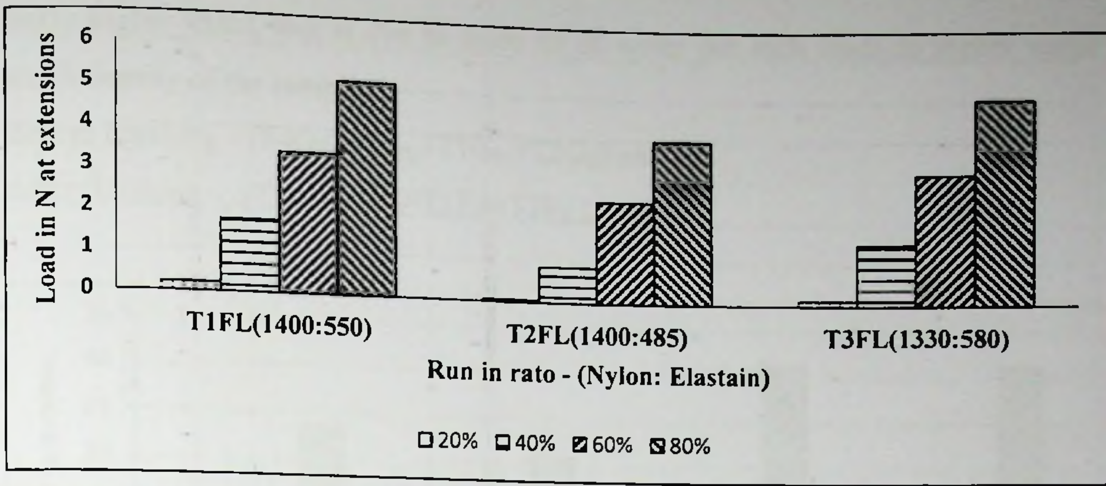

Figure 4.6- Load at different extensions of finished fabrics - length direction

4.2.3 Stretchability of finished fabric samples in width direction

Table 4.6 shows the load at 20% extension on the width direction of the finished fabric samples.

Table 4.11- Load at 20% extension of finished fabric samples – width direction

Sample	Run-in in mm (Nylon : elastane)	Load at 20% extension	Greige fabric		Finished Fabric	
			Wales /inch	Courses / inch	Wales / inch	Courses / inch
Constant – Nylon yarn run-in						
T1F$_E$	1400:550	1.35	84	128	64	128
T2F$_E$	1400:485	1.25	84	128	64	136
Constant – Nylon yarn run-in						
T3F$_E$	1330:580	2.02	84	126	64	125
T4F$_E$	1330:550	2.45	84	124	68	126

The load at 20% extensions in the width direction of the finished fabric, are comparatively higher than the length direction of the finished fabrics. After finishing the fabric, results of all the samples show that the wales per inch is reduced and courses per inch is increased except T1F$_E$ and T3F$_E$. Therefore values of load at different extension level of length direction is lower than the greige samples. T4F$_E$sample shows fairly higher value, this is due to more no of wales per inch leads to higher value of stitch density of the sample.

Before finishing - ($T4G_E$>$T3G_E$>$T1G_E$>$T2G_E$) and

After finishing – ($T4F_E$>$T3F_E$>$T1F_E$>$T2F_E$).

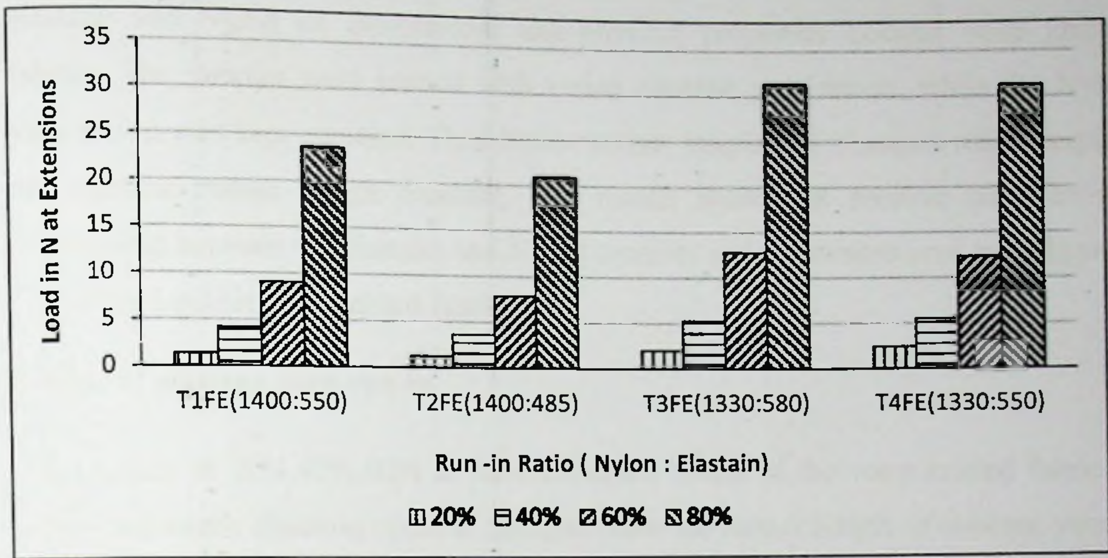

Figure 4.7- Load at different extensions of finished fabrics -width direction

After finishing the all four fabric samples load at 20%, 40%, 60% & 80% extension levels have been increased. But samples which is having higher run in ratios shows small incremental value of the load at 20%, 40%, 60% & 80% extension levels.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The main objective of this study is to investigate the effects of different percentages of elastane and Nylon on dimensional and physical properties Locknit warp knitted fabrics. The samples were knitted with varied elastane yarn run-in, while the Nylon yarn run-in was kept constant. Then Nylon runner length was changed while keeping the elastane runner length constant. The results show that positive trend in the relationship between the elastane and Nylon contents and the dimensional and physical properties Locknit warp knitted fabrics.

Effects of elastane yarn run-in

Load values at 20%,40%,60% & 80% extension levels of the warp knitted fabric in length and width direction could is changed when the runner length of elastane yarn is changed. Shorter run-in length of elastane yarn with the higher run-in ratio tends to make higher tightness factor value in the fabric. Elastane yarn run-in length influences the stretchability of the length direction of the fabric in greige stage. The length direction stretchability of finished fabric is one of the most important parameter for body fit garments.

As discussed under literature review the wearer prefers a low force at high stretch value of fabric when making a garment. This can be obtained with comparatively less amount of elastane percentage, when the fabric has a higher value of run in ratio.

There is no significant effect of elastane run-in length on wales density of the fabric. Higher value of run-in ratio highly influences the load at 20% extension value of the Locknit fabric in length direction.

Effects of Nylon yarn run - in

Nylon yarn percentage effects on course density and fabric weight. Further it affects the values of load at 20%, 40%, 60% & 80% extension levels of the fabric in width direction. Results have been shown that higher stretchability of fabric which was knitted with higher runner length of Nylon yarn (more amount of percentage of Nylon) while maintaining the low run- in ratio value of the fabric. It helps to get better performance in body fit garments.

More amount of Nylon yarn percentage with the lower value of run in ratio of the fabric, gives better performance in body fit garments. Further improvement in stability of length direction could be improved by decreasing the run-in of Nylon yarn. However it is needed to be further investigated to find the optimum level of elastane and Nylon percentage.

Effect of run-in ratio of elastane and Nylon on physical properties of the fabric

This study reveals that there is a relationship with stretchability in length and width direction and the run-in ratio of the fabric. The sample which is made from the run-in of 485mm elastane yarn and the run-in of 1400mm Nylon yarn shows the highest run in ratio value among the four samples. It is having the highest values of load at 20%, 40%, 60% and 80% extensions in length direction and the lowest values of load at 20%, 40%, 60% and 80% extensions in width direction. Hence there was a correlation between the length and width direction stretchability and the run-in ratio of the greige sample. Run-in ratio of elastane and Nylon influences the course density value of the greige a fabric as well. Further investigation would be required to determine the optimum correlation between the stretchability and the run-in ratio of the greige sample

5.2 Recommendation

Same study could be extended further to investigate the stability of the achieved results and to find out the optimum amount of elastane and Nylon percentage in order to get the low values of load at different extension level which needs for body fit garments.

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Appendix 1.a – Data collected to investigate the dimensional properties of the greige and finishedfabrics- Fabric weight in g/ m2 and courses and wales density

Sample T1 – Nylon: elastane 1400:550							
Specimen No	**T1G - Greige Sample**			**Specimen No**	**T1F- Finished Sample**		
	CPI	**WPI**	**GSM**		**CPI**	**WPI**	**GSM**
1	128	84	254	1	128	64	192
2	129	84	255	2	129.5	64	190.3
3	128	84	254	3	128	64	189
4	129	84	253	4	128	64	190.3
5	127	84	253.5	5	129	64	189
Average	**128.4**	84	**253.9**	Average	**128.4**	**64**	**190.1**

Sample T2 – Nylon: elastane 1400:485							
Specimen No	**T2G - Greige Sample**			**Specimen No**	**T2F- Finished Sample**		
	CPI	**WPI**	**GSM**		**CPI**	**WPI**	**GSM**
1	128	84	251	1	136	64	195
2	130	84	250.5	2	137	64	195
3	129	84	250.5	3	136	64	195.4
4	128	84	250.5	4	135	64	196.3
5	127	84	251.4	5	136	64	195.2
Average	**128.4**	**84**	**250.78**	**Average**	**136**	**64**	**195.38**

Sample T3 – Nylon: elastane 1330:580							
Specimen No	T3G - Greige Sample			Specimen No	T3F- Finished Sample		
	CPI	**WPI**	**GSM**		**CPI**	**WPI**	**GSM**
1	126	84	247.8	1	125	64	185.2
2	126	84	245.8	2	125	64	183.5
3	127	84	245.8	3	125.5	64	184.6
4	126	84	247	4	125	64	184.4
5	126	84	248	5	126	64	184.8
Average	**126.2**	**84**	**246.9**	**Average**	**125.3**	**64**	**184.5**

Sample T4 – Nylon: elastane 1330:550							
Specimen No	T4G - Greige Sample			Specimen No	T4F- Finished Sample		
	CPI	**WPI**	**GSM**		**CPI**	**WPI**	**GSM**
1	124	84	245	1	126	68	190.8
2	124	84	246	2	125.5	68	193
3	124	84	245	3	127	68	194.5
4	124	84	245.5	4	126	68	194
5	124	84	245	5	125.5	68	193.7
Average	**124**	**84**	**245.3**	**Average**	**126**	**68**	**193.2**

Fabric width – Greige Sample

Specimen no	T1G 1400:550	T2G 1400-485	T3G 1330-580	T4G 1330-550
1	152	152	156	152
2	152	152	156	152
3	152	152	156	152
4	152	152	156	152
5	152	152	156	152
Average	**152**	**152**	**156**	**152**

Bursting strength -Geige and finished sample

Specimen no	**T1G 1400:550**	**T2G 1400-485**	**T3G 1330-580**	**T4G 1330-550**
1	**Did not Burst**	**Did not Burst**	**Did not Burst**	**Did not Burst**
2	**Did not Burst**	**Did not Burst**	**Did not Burst**	**Did not Burst**
Specimen no	**T1F 1400:550**	**T2F 1400:485**	**T3F1330:580**	**T4F1330:550**
1	**Did not Burst**	**Did not Burst**	**Did not Burst**	**Did not Burst**
2	**Did not Burst**	**Did not Burst**	**Did not Burst**	**Did not Burst**

Appendix 1.b- Data collected to investigate the stretchability of the fabric before and after finishing process- length and width direction of the fabric

Sample T1 - Run-in (1400:550) - (Nylon : elastane)									
Specimen no	$T1G_L$ - Greige Fabric – Length direction				Specimen no	$T1G_E$ - Greige Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	4.841	8.833	12.83	18.37	1	1.2	2.59	3.8	5.01
2	4.776	8.886	13.04	18.85	2	1.07	2.477	3.779	5.027
3	3.952	8.26	12.05	17.2	3	1.308	2.792	4.141	5.348
4	4.355	8.518	12.38	17.74	4	1.61	2.982	4.19	5.423
5	3.779	7.927	11.56	16.13	5	1.533	2.974	4.183	5.397
Average	4.3406	8.4848	12.372	17.658	Average	1.3442	2.763	4.0186	5.241
Specimen no	$T1F_L$ - Finished Fabric - Length Direction				Specimen no	$T1F_E$ - Finished Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	0.13	1.804	3.315	5.055	1	0.4	2.482	5.269	9.923
2	0.13	1.713	3.4	5.203	2	1.586	4.554	9.925	26.85
3	0.26	1.897	3.641	5.442	3	1.34	3.973	7.957	18.1
4	0.26	1.819	3.508	5.309	4	1.808	5.034	11.47	32.85
5	0.26	1.518	3.17	4.901	5	1.64	4.76	10.58	30.52
Average	0.208	1.7502	3.4068	5.182	Average	1.3548	4.1606	9.0402	23.6486

Sample T2 - Run-in (1400:485) - (Nylon : elastane)									
Specimen no	$T2G_L$ - Greige Fabric – Length direction				Specimen no	$T2G_E$ - Greige Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	5.252	10.027	15.15	23.01	1	0.755	2.283	3.562	4.973
2	5.507	10.336	15.84	24.39	2	0.98	2.699	4.049	5.529
3	4.747	9.648	14.78	22.41	3	0.93	2.415	3.801	5.141
4	4.981	9.889	15.14	23.00	4	0.873	2.332	3.772	5.115
5	4.952	9.769	14.8	22.38	5	0.909	2.455	3.827	5.167
Average	5.0878	9.9338	15.142	23.038	Average	0.8894	2.4368	3.8022	5.185
Specimen no	$T2F_L$ - Finished Fabric - Length Direction				Specimen no	$T2F_E$ - Finished Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	0.04	0.93	2.594	4.074	1	0.925	2.73	5.3	10.58
2	0.13	0.8	2.411	3.884	2	1.29	3.88	8.66	24.57
3	0	0.779	2.433	3.926	3	1.148	3.35	7.232	17.62
4	0	1.162	2.766	4.312	4	1.594	4.51	9.934	28.92
5	0.11	0.69	2.32	3.93	5	1.332	3.82	8.371	23.03
Average	0.056	0.8722	2.5048	4.0252	Average	1.2578	3.658	7.8994	20.944

Sample T3 - Run-in (1330:580) - (Nylon : elastane)									
Specimen no	$T3G_L$ - Greige Fabric – Length direction				Specimen no	$T3G_E$ - Greige Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	3.524	8.141	12.03	16.97	1	1.34	2.811	4.161	5.501
2	2.559	7.678	11.42	16.07	2	1.61	3.134	4.37	5.712
3	2.99	7.945	11.7	16.22	3	1.653	3.152	4.362	5.739
4	1.509	7.194	10.81	14.78	4	1.615	3.033	4.373	5.715
5	2.953	7.947	11.71	16.31	5	-	-	-	-
Average	2.707	7.781	11.534	16.07	Average	1.5545	3.0325	4.3165	5.66675
Specimen no	$T3F_L$ - Finished Fabric - Length Direction				Specimen no	$T3F_E$ - Finished Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	0.13	1.254	2.864	4.609	1	1.88	4.65	10.21	29.48
2	0.13	1.494	3.168	4.984	2	1.96	5.04	11.49	33.28
3	0.13	1.656	3.319	5.146	3	2.04	5.57	13.85	-
4	0.13	1.478	3.223	5.036	4	2.17	5.7	14.54	-
5	0.142	1.717	3.467	5.428	5	2.09	5.5	14.08	-
Average	0.1324	1.5198	3.2082	5.0406	Average	2.02	5.29	12.83	31.38

Sample T4 - Run-in (1330:550) - (Nylon:elastane)									
Specimen no	$T4G_L$ - Greige Fabric – Length direction				Specimen no	$T4G_E$ - Greige Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	4.622	9.442	13.95	20.15	1	2.119	3.579	4.841	6.269
2	4.357	9.039	13.51	19.35	2	2.017	3.434	4.747	6.095
3	4.606	9.38	13.94	20.11	3	1.902	3.318	4.626	5.966
4	4.418	9.216	13.58	19.46	4	2.084	3.396	4.721	5.946
5	3.49	8.733	12.79	18.11	5	1.902	3.478	4.818	6.298
Average	4.2986	9.162	13.554	19.436	Average	2.0048	3.441	4.7506	6.1148
Specimen no	$T4F_L$ - Finished Fabric - Length Direction				Specimen no	$T4F_E$ - Finished Fabric – Width direction			
	Load at Extension in N					Load at Extension in N			
	20%	40%	60%	80%		20%	40%	60%	80%
1	0.67	2.483	4.355	6.352	1	2.346	4.999	10.22	28.95
2	0.67	2.432	4.202	6.184	2	2.274	5.249	11.19	33.63
3	0.67	2.562	4.442	6.454	3	2.357	5.446	11.99	----------
4	0.701	2.448	4.394	6.404	4	2.733	6.177	14.75	----------
5	0.8	2.708	4.588	6.631	5	2.551	5.832	13.49	----------
Average	0.7022	2.5266	4.3962	6.405	Average	2.4522	5.5406	12.328	31.29