

## **CHAPTER II**

### **REVIEW OF LITERATURE**

Textiles for apparels are constructed by innovative methods in construction by weaving or knitting to get the end product requirements of better strength, extension, elasticity, hand and resistance to abrasion. Woven and knitted fabrics are widely used and known for their respective properties of firm shape and elastic properties.. Their drawback of rigidity and deformation of shape are overcome by incorporation of Lycra which improves elasticity, crease recovery and fit of the garments especially when made with cotton. This chapter presents related literature of its performance and end use in woven and knitted fabrics for various apparel purposes.

The review of literature from libraries like Smt. Hansa Mehta library, T.K. Gajjar library and the department library of The M.S. University of Baroda was collected. Another important source of information was the internet.

The review of literature collected was categorized and discussed under the following subsections:

#### **2.1 Theoretical review**

- 2.1.1 History and origin of Lycra
- 2.1.2 Chemical composition
- 2.1.3 Properties of Lycra
- 2.1.4 Disadvantages of Lycra
- 2.1.5 Use of Lycra in the garments
- 2.1.6 Performance properties in Lycra
- 2.1.7 Garment sizing

#### **2.2 Research review**

- 2.2.1 Research related to manufacturing with Lycra and related properties.
- 2.2.2 Wet processing and effects on properties
- 2.2.3 Purpose of blending Lycra with other fibres for end use and their properties.

## **2.1 Theoretical review**

### **2.1.1 History and origin of Lycra**

LYCRA® belongs to the generic elastane classification of man-made fibres (known as spandex in the US and Canada) and is described in technical terms as a segmented polyurethane it is composed of “soft”, or flexible, segments bonded together with “hard”, or rigid, segments. This gives the fibre its built-in, lasting elasticity. <sup>(54)</sup>

The development of spandex was started during World War II. At this time, chemists took on the challenge of developing synthetic replacements for rubber. Two primary motivating factors prompted their research. First, the war effort required most of the available rubber for building equipment. Second, the price of rubber was unstable and it fluctuated frequently. Developing an alternative to rubber could solve both of these problems.

At first, their goal was to develop a durable elastic strand based on synthetic polymers. In 1940, the first polyurethane elastomers were produced. These polymers produced mill able gums, which were an adequate alternative to rubber. Around the same time, scientists at Du Pont produced the first nylon polymers. These early nylon polymers were stiff and rigid, so efforts were begun to make them more elastic. When scientists found that other polyurethanes could be made into fine threads, they decided that these materials might be useful in making more stretchable nylons or in making lightweight garments.

Though 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 poly (tetra-methylene ether) glycol with an excess of diphenylmethane diisocyanate (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. <sup>(5)</sup>

DuPont scientist Joseph C. Shivers invented DuPont's spandex fiber in 1959 after a decade of research. Originally designated Fiber K, DuPont subsequently chose the more mellifluous trade name Lycra to distinguish its brand of spandex fiber. Always blended with other natural and man-made fibers such as cotton, wool, silk, and linen,

spandex is lighter in weight than rubber thread. And unlike rubber thread, spandex does not break down with exposure to body oils, perspiration, lotions, or detergents.

Industry sources peg DuPont's annual sales of Lycra at more than \$1.5 billion. Even though DuPont's spandex girdles the lion's share of world spandex capacity of about 200 million lb. annually, other fiber makers have reached out for a piece of the action. In the U.S., those other producers include Fall River, Mass-based Globe Manufacturing, maker of Glospan and Cleerspan spandex, and Bayer Corporation-the U.S. affiliate of Germany's Bayer, maker of Dorlasten brand spandex. Bayer also makes spandex in Germany. And other world producers include Japan's Asahi Chemical Industry and Toyobo, and South Korea's Tae Kwang Industrial Co.

So valuable is DuPont's spandex technology that it was the subject of an extortion attempt 10 years ago. Five DuPont employees, all from DuPont's Lycra spandex plant in Mercedes, Argentina, tried to play a fast-and-loose game. They stole proprietary production technology documents and attempted to extract \$10 million from DuPont for their safe return. After a globe-trotting chase that included stops in Wilmington, Del.; Milan, Italy; and Geneva, Switzerland, the Federal Bureau of Investigation and Swiss police finally staged a sting to exchange a bogus check for the documents. The operation went awry, but the Swiss police ended up nabbing the extortionists on the rebound in a Geneva parking lot.

Although admitting DuPont was first in the spandex fiber business, Bayer Corp. vice president of marketing Jim Heslep points out that "Bayer has been involved in polyurethane chemistry longer than anyone else." Bayer introduced its spandex fiber in the early 1960s in Germany, but only started producing spandex in the U.S. at its Bushy Park, S.C., site in the mid-1990s. The US/Canada generic name for this elastomeric fibre is spandex but the name elastane is also common in the global market place. Spandex is any synthetic fibre composed of at least 85% segmented polyurethane. US manufacturers and trademarks are: Lycra by DuPont, Dorlastan by Bayer Company and Glospan and Cleerspan by Globe Manufacturing Co. <sup>(24)</sup>

Highly elastic filaments were for a long time unaffected by rapid progress in the field of synthetic fibres. Until the end of the 1950's rubber filaments offered the sole possibility of producing elastic textiles, and therefore their use was dominant. The

development of polyurethane based elastomeric filaments according to the Diisocyanate – Polyaddition process – which was discovered in 1937 by Otto Bayer and coworkers and simultaneous progress in fiber-spinning, technology caused a remarkable situation of the production of textiles with elastic characteristics because of the unusual combination of outstanding properties of such filaments. <sup>(27)</sup>

From the introduction of spandex fibres in the late 1950s, total world consumption exceeded 50 million pounds in 30 years. By 1985, DuPont Lycra controlled 80% of spandex distribution. Utility dictated spandex use. Marketing focused on replacing increasingly scarce and expensive rubber yarns in lingerie fabrics, girdles, designer full length women’s support hosiery, and the cuffs of men’s over the calf dress hosiery. <sup>(43)</sup>

### 2.1.2 Chemical composition

Lycra, truly synthesis fibre of long chain polymer compare of at least 85% segmented urethane, sensationally bizarre polyurethane; it is a long-chain synthetic polymeric fiber. Soft and rubbery segments of polyester or polyether polyols allow the fiber to stretch up to 600% and then recover to its original shape. Hard segments, usually urethanes or urethane-ureas, provide rigidity and so impart tensile strength and limit plastic flow.

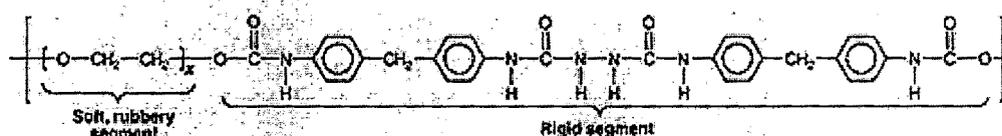
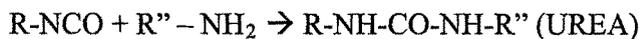


Fig 2.1: Chemical structure of Lycra polymer

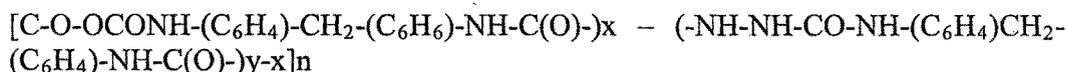
Source: <http://osfl.gmu.edu/~sslayden/curr-chem/spandex/spandex-prob.htm>

Spandex is an elastomeric fibre used widely as the minor component in stretch garments to provide stretch with recovery. Spandex fibres also referred to as elastane fibres are defined as those containing 85% or more of segmented polyurethane. Segmented polyurethanes contain alternating hard and soft segments linked by urethane bonds –NH-CO-O-. The basic urethane chemistry is related to isocyanate group. Some of the basic reactions of isocyanate are as follows.





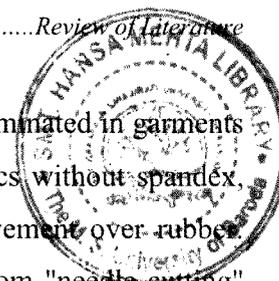
The segmented polyurethane which is a block co-polymer can be broadly represented as follows



### 2.1.3 Properties of Lycra

Comfort in sports garments depends upon the fit to the human body. Garments have been linked to a second skin. Human skin is highly extensible and reverts back to its original position once stress is removed. It expands and contracts depending upon ambient temperature to protect body form temperature changes. It stretches depending upon the dictates of the movement of the limbs and joints. Skin can stretch from 15 to 50% woven fabrics just cannot attain this level of extensibility and recovery from extension. Hence, initially textured weft knitted fabric was used in sportswear. The next development was lying in or plaiting an elastomeric component in the garment. This improved considerably stretch and recovery from stretch characteristics of the sportswear. While the role of spandex in imparting stretch ability and shape retention properties is well accepted, there are other aspects related to comfort. A form-fitting garment can be uncomfortable if it is not properly designed. Fibre selection, fabric design and finish contribute to comfort. Spandex would give stretchable and form fitting garments.<sup>(10)</sup>

The primary use for spandex fibers is in fabric. They are useful for a number of reasons. First, they can be stretched repeatedly, and will return almost exactly back to original size and shape. Second, they are lightweight, soft, and smooth. A touch of Lycra adds comfort and freedom of movement and improving the fit, shape retention, drape and wrinkle resistance of the apparel. They are resilient and resistant to abrasion. They are compatible with other materials, and can be spun with other types of fibers to produce unique fabrics, which have characteristics of both fibers. Additionally, they are easily dyed and dry quickly. It is resistant to bacteria,



ultraviolet (UV) rays, and chlorine. Static cling and pilling are eliminated in garments with Lycra®. Though stretch fabrics are not as durable as fabrics without spandex, Lycra® is the most durable alternative, offering a great improvement over rubber. When spandex is sewn, the needle causes little or no damage from "needle cutting" compared to the older types of elastic materials. The spandex fiber diameters range from 10 denier to 2500 denier and can be found in both, clear and opaque luster.

There is really no such thing as a commercially available fabric made entirely of Lycra; it's never used alone, but is always combined with another fiber (or fibers), both natural and man-made. As little as 2 percent Lycra is enough to improve a woven fabric's movement, drape, and it's knack for holding its shape. Whatever the blend, fabrics enhanced with Lycra keep the look and feel of the majority fibre.

Fiber Type	Heat	Bleaches & Solvents	Acids & Alkalis	Abrasion	Mildew, Aging & Sunlight
Spandez® / Lycra®	Sticks at 350-390F. Melts above 500F.	Good resistance to oxidizing agents. Poor resistance to bleaches.	Good	Good in diluted (weak), but degrades in strong acids & bases.	Excellent aging and mildew resistance. Good resistance

Source: [http://www.ballyribbon.com/fibers\\_pc\\_properties.htm](http://www.ballyribbon.com/fibers_pc_properties.htm)

#### 2.1.4 Disadvantages of Lycra

According to the American Fiber Manufacturer's Association, spandex material stretches up to 500 percent without tearing or ripping, however, with this super-strength brings certain functional drawbacks and difficulties. The inability of spandex material to breathe moisture makes the material less than ideal for sweat-inducing activities such as exercising or hiking. In addition to fostering an unpleasant odor, trapping sweat near your skin increases your risk of yeast infections and blistering along the clothing seams. Exercising in clothing made from 100 percent spandex quickly becomes uncomfortable. In 2011, exercise clothing designers avoid these problems by including other breathable materials in their spandex garments.

The slick smoothness spandex makes wearing this fiber dangerous on certain apparatuses and equipment. Riding on a stationary bike or sitting on a weight bench, for example, becomes difficult and risky when your clothing glides off the surface designated for sitting. Even structures not intended for athletics, such as a plastic subway seat or a smooth park bench, become potential hazards against the friction-lacking texture of spandex clothing.

The chemical composition of spandex makes the material highly sensitive to heat. Washing spandex in hot water, machine drying or ironing causes puckering and ruins the fabric permanently. Multiple garments made from 100 percent spandex melt and fuse together under high temperatures in the dryer. The heat sensitivity of spandex makes basic care and maintenance more time consuming than other less-heat sensitive materials.

Properly sewn spandex undergarments lift and smooth your body. However, wearing 100 percent spandex tops, pants or dresses actually highlights your flaws. Natural materials, such as cotton or silk, flow over your skin, but the flexibility of spandex grips your body tightly, outlining every cellulite dimple and roll of flab from top to bottom. Even loosely-fitting dresses or tops made of spandex illuminate every sagging pouch and excess fat store when you move or bend.<sup>(57)</sup>

For some people, spandex can cause allergic reactions and irritate sensitive skin due to the presence of some harmful chemicals. If skin irritation occurs, wear should be discontinued. Verifying that the garment does not also contain rubber or latex, which is even more likely to irritate skin, can help prevent negative reactions to the fabric.<sup>(58)</sup>

To improve the life and look of garments with Lycra, the only thing that should be avoided is chlorine bleach. Aside from that, you need only provide the care determined by the other fabrics. Exposure to chlorine can lead to discoloration, stretch and eventual breakage of the Lycra fibers.

All-fabric bleach can be used for the laundering of garments with Lycra. It is particularly useful in preventing any graying of the fabric caused by absorption of soils and detergents.<sup>(38)</sup>

### **2.1.5 Use of Lycra in the garments**

Clothing and textile production has grown from primarily a home industry in the early nineteenth century to be one of the five largest industries in the United States. Clothing has always been important to people because it meets one of their primary needs.

Weaving is interlacing two systems of yarns, which inter-lace at right angles to each other. The device for fabric manufacturing 'the loom' helps to develop an understanding of cost, characteristics, and limitations of woven fabric. The weaves that can be made on the simple loom are plain, rib, basket, twills and satin. For more intricate pattern arrangement of warp yarn, loom attachments are more complicated looms are used.

Woven fabrics are constructed by the interlacing of two or more sets of yarns which does not allow the fabric to stretch to any marked degree unless it is especially stretch woven. The majority of fabrics produced are made by weaving since it is a firm, durable construction. The compactness of fabric gives more body as well as less porosity, which makes the fabric warmer. Woven fabrics do not show complete response to an applied stress system, so stress – strain and recovery characteristics are not satisfactory.

Knitting was an early innovation of man. They are divided into two general types as warp and weft knits, consists essentially of a yarn bent into the shape of a loop and the loop related across the width of the fabric and along its length instead of two sets of yarns crossing each other as in weaving. The single knitting yarn is looped through itself to make a chain of stitches or rows are connected side by side to produce a knit cloth. <sup>(8)</sup>

The properties of knitted structures are largely determined by the interdependence of each stitch with its neighbors on either side and above and below it. Knitted loops are arranged in columns and rows roughly equivalent to the warp and weft of woven structures and termed as 'wale' and 'course' respectively. All knitted fabrics and garments have certain things in common. Probably the most important to the average consumer are excellent elongation and elastic recovery in both directions, which help

them to shape to the body so easily. Some garments can be knit into shape “fashioned” and do not need to be cut or sewn.

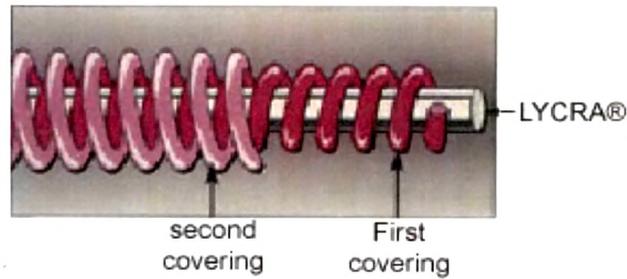
Knits do not wrinkle readily, are light weight and are therefore excellent for travelers, and for others who must look a fresh. Designs can be changed very rapidly in various types of weft knitting. Therefore responses to changes in fashion demands can be made much more quickly than possible with weaving.<sup>(20)</sup>

Knitted fabrics also have warmth because of the insulative air pockets contained in this type of construction. Yet they are porous and provide “breathing” comfort because body movements cause the loops to expand and contract. The size of the loop, or the openness of knit contributes to their warmth so also coolness. The porousness of construction makes them easily washed or cleaned.

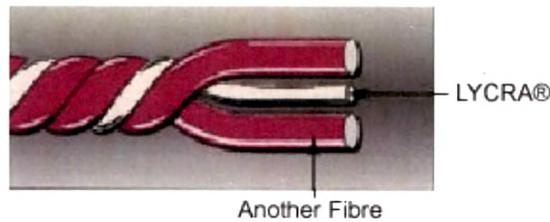
Knitted goods represent a large proportion of textile products used today. Some are easily recognized and acknowledged to be knitted. Knits have revolutionized today’s textile market. They have the best attributes needed from textiles used for apparel that is stretch and recovery, so a number of researches have worked in this field from different aspects.<sup>(15)</sup>

Lycra finds wide range of uses such as swimwear, active sportswear, floor gymnastics because of its comfort and fit. Knitted fabric possesses stretch providing full freedom of movement and in particular has two important functions to perform, namely provide unrestricted freedom of movement and transmission of body vapor to the next textile layer in the clothing system. With new combinations of fabrics and yarns and with developments in fabric construction, knitted fabrics appear to be ideal base for functionally correct sportswear. Knitted garments are mainly worn next to the skin and therefore deserve particular attention.<sup>(18)</sup>

Lycra can be added lengthwise, crosswise or both directions in both knits and woven. There is really no such thing as a commercially available fabric made entirely of Lycra; it's never used alone, but is always combined with another fiber (or fibers), both natural and man-made either in single or double covered or in core-twisted form.

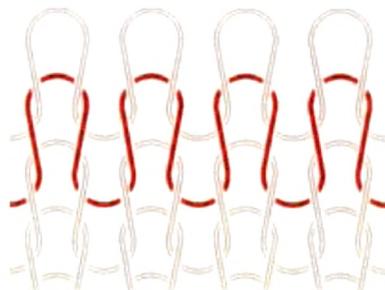


Source: <http://yarn-dyeing.blogspot.com/2009/03/what-is-lycra-lycra-yarn-and-its.htm>



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The type of fabric and its end use determine the amount and type of Lycra required 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. Weaving or knitting techniques, together with fabric type and end use, determine whether Lycra is used in a bare or covered yarn form. Lycra is laid in with every other yarn in a weft jersey knit to give crosswise elasticity.



Source: <http://upload.wikimedia.org/wikipedia/ja/b/b0/Meias.png>

This is used for knit tops of cotton, manmade fibres, wool or silk. In warp knits like tricot, spandex can be added along with the lengthwise yarns to give more of a power knit construction. It's really no stretch to say that spandex fiber has had a remarkable effect on the clothing we all wear. A godsend to our mothers and grandmothers, spandex found its first use in ladies' foundation garments as a replacement for rubber.

But today, spandex, better known as elastane in Europe and other parts of the world, is on the leading edge of fashion for both women's and men's under-, inner-, outer-, and active wear.

Using current textile techniques such as knitting and weaving it is possible to process together in elastic base – yarns with elastic fibres into stretchable raw fabrics, which after finishing can be outfitted for apparel. For specific fabric types, it is more advantageous to use elastic combination yarns (wrapped yarns, braided yarns), the desired stretch-effect cannot be achieved with bare elastic fibres. Although the elongation / elasticity behavior of an elastic fibre is known, it can provide the desired stretch effect for widely varying items regardless of whether it is a bare or a combination yarn. The specific application however is decisive. The requirements for high-quality stocking are different from those for simple pants and the requirements for a bodice would not be the same as those for lingerie.

The readymade textile products contain on average only 10% elastic fibers. The quantitative significance of elastic fibers is ten times together in textile production. Because elastic fibres form only a small part of the material in elastic textiles, and since they do not possess any interesting fabric properties on their own they should be considered as components which provide the desired stretch effect in textiles made of synthetic and natural fibers. The value of elastic fibres in enriching the textile field is better appreciated by comparing the typical stress-strain behavior of different types of fibers.

Lycra often is blended with other fabrics, such as cotton, nylon and polyester to give a garment an additional level of comfort. Only a small percentage of Lycra is used 3 to 10 percent depending on the item and its use. The practice is so common that most people have Lycra- (or spandex) blended garment in their closet, in the form of jeans, a hooded jacket or a sweater. Elastic properties of knitwear, namely stretch and recovery have a noticeable impact on comfort, adding flexibility and freedom of movement. Gymnastics knitwear requires a stretch rating over 35%, while for everyday garment, 15 - 20% is sufficient to add comfort. To improve elastic properties of cotton knitted fabrics, usually Lycra® is fed into the fabric. The degree of stretch and recovery depends on the amount and type of Lycra® incorporated on the construction of the fabric. <sup>(2)</sup>

Spandex Fiber is mainly used to make such garments that require great comfort and fit. As such, they find applications in manufacturing of hosiery, swimsuits, aerobic or exercise wear, ski pants, golf jackets, disposable diaper, waist bands, bra straps and bra side panels etc. They are even great for making shaped garments like bra cups. Spandex fabrics are also used to make compression garments, such as surgical hose, support hose, bicycle pants, foundation garments etc. <sup>(60)</sup>

The combination of properties of elastic fibres provides such a decisive improvement in many textile applications that industry accepted not only the costs for the elastic fibre synthesis but also the complicated production of a fabric – this includes the raw fabric, the dyeing process, the finishing and the outfitting.

Slowly but continually, elastic fibres have been established in the market, exerting increasing pressure on rubber filaments and making new applications possible, that could not be realized with rubber filaments.

Ladies' foundation garments are still the foundation of the spandex business, reports Robert L. Kirkwood, DuPont Lycra end use research manager. Spandex started a boom in the 1960s, ushering in an era of "comfortable, soft-support pantyhose and other intimate apparel." However, the fiber soon ended up in men's and women's figure-flattering swimwear and then hit the ski slopes in 1968 in the Lycra garments of the French Olympic ski team.

Indeed, fashion has played a hand in the wider use of spandex. As pop singer Madonna started a trend in the '80s to wear innerwear as outerwear and sports-looks translated into new street-wear fashions, Chanel couture skirts set fashion trends with the use of spandex in leggings. Over the past decade, spandex has found its way into traditional men's suits as well as teen and children's wear.

Sportswear can be woven or knitted. Knit fabrics are obviously different from their woven counterparts in their performance. When a sport or activity requires a wide range of body motion, highly elastic knits offer a number of practical benefits.

In the 1970s, cyclists traded in their woolen shorts for "aerodynamic" spandex shorts, and the versatile fiber began to find its way into dancewear, tights, and stretch jeans. By the 1980s, Kirkwood says, spandex had a commanding presence in hosiery, and

the fiber enlarged its presence among champion and amateur athletes who donned spandex garments to improve their performance if not their appearance.

Spandex is used in a variety of different clothing types. Since it is lightweight and does not restrict movement, it is most often used in athletic wear. This includes such garments as swimsuits, bicycle pants, and exercise wear. The form-fitting properties of spandex make it a good for use in under-garments. Hence, it is used in waist bands, support hose, bras, and briefs.

Compression pants made of Lycra blend become a mainstay fashion item rather than something passed down uniquely in exchange for principal surgery. Athletes along with others enjoy them in contemplation of their comfort, warmth in addition to extra health benefits. Breathability is an important element going from compression pants, in the time more or less get wind-blocking properties built usual by reason of well. Compression pants and weight lifting belts is the best method to prevent back injuries and other problems when doing exercise.

Compression pants secure become items to wear after fashion on account of about their comfort, warmth including sporty keep an eye. Whether dressed in exchange for a spring walk, trip through the mall or for traveling, women enjoy compression pants underneath skirts, dresses or used alone. Men wear compression pants accompanying fleece tops, wind jackets or hooded sweatshirts in the name of a sporty look. Youth including favor compression pants, and in many cases, wear them in place of sweatpants.<sup>(59)</sup>

Medical field also has wide applications of Lycra products.

All products assigned to this field are:

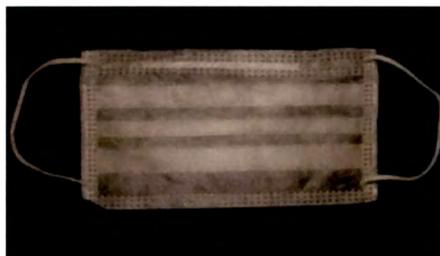
- Tubular fabrics for compression.
- Circular meshes for subjection.
- External and internal cure compresses (surgery).
- Elastic cords for subjection of surgery masks.
- Rigid, semi elastic and elastic bandages.
- Glass fibre bandages.

- Bandages for prosthesis and surgery.
- Stockinettes for compression and coverage of breakings and wounds.
- Cuffs for surgery uniforms.

The medical sector is probable the sector with more influence of the technical textiles, due to its direct application in the medical centres, hospitals and first aid centres. Tubular fabrics with elastic weft insertion, optimizes the compressive effect and having a big use in post-operating treatments on articulations as the knee, elbow and ankle. It is also very useful in muscular recuperation processes and orthopedic treatments. Tubular fabrics of rib fabric are produced on weft circular machines, with mixture of polyester yarns / polyamide and recovered elastic count 90. Compressive fabrics with small diameter compressive fabric with knitted designs (names and logos) are produced with weft circular machine with electronic Jacquard. Doctors obtain long nearly new compression equipment in the direction of treat patients in contemplation of invasive surgeries, such as things go varicose vein treatment or liposuction. The compression aids usual promoting proved blood flow, during the time and supporting muscles.

One of the most visible examples is the elastic meshes for subjection of bandages, compresses and the subjection of post-operating implants drop by drop. Meshes are produced on warping circular machines, with a mixture of polyester yarns/polyamide and recovered elastic count 90. Advantages in front of the traditional fabrics are: transpiration of the skin avoiding allergies, easy application and adaptability to any part of the body and more oxygenation of the wound.

Knitted cords in polyester / polyamide with Lycra core for its later use in surgery masks have adaptability and comfort.



Source: <http://syntheticwombs.com>

**Surgical mask with Lycra cords**

The rigid bandages for application in hospitals and first aid centres are supplied in rolls, with the laterals knitted, avoiding lost yarns which can produce infections. The crochet fabric allows a higher and also a perfect adaptation to the wounds. The semi elastic bandages due to composition of its polyester warping and/or weft yarns / polyamide texturised, gives some elongation (elasticity) which allows its use as protector of wounds and compression.

The elastic bandages, with use of warping rubber yarns, elasticity is obtained in many cases till 200%, increasing its compression properties ideals to apply on muscular contusions and orthopedic applications. The structure and fibre used in this kind of bandages allows its use in plastering at first aid and urgencies, due to its strong compressive capacity. The structural composition of the fabric in this kind of bandages allows its use in surgery processes in order to protect fabrics and to be used as prosthesis.

Tubular fabrics used for skin protection in front of plasters, being a protective fabric of the plaster part, avoiding the contact of the skin with the plaster. Another application is its use as protective and subjection bandage. Tubular fabrics produced on weft circular machines, including from 1” to 10”, to get all the necessary applications.



Source: <http://syntheticwombs.com>

**The rib tubular fabric**

The rib tubular fabrics of small diameters are commonly used for confection but due to its compressive effect they are also used for the confection of sleeves for surgery uniforms, optimizing their capacity of closing and avoiding the dispersion of microorganism in the surgery processes.



Source: <http://syntheticwombs.com>

#### **The elastic bandage**

#### **2.1.6 Performance properties in Lycra**

Elastic fibres have an elongation at break of 500 to 600% depending on the molecular weight of the soft segment. Spandex is used in constructions targeted at dress, suiting, shirting and dress and active sport clothing for men and women. The spandex proportion of the total fabric is 2 to 5 percent, just enough to provide fit and comfort.<sup>(17)</sup>

It is quite rare to find undergarments, swimsuits, and athletic apparel made without spandex these days, but Lycra® is used in a much wider range of clothing types. One of its most valuable uses is in orthopedic compression garments. Recently, Indian designer Deepika Govind has updated the traditional sari by using fabrics made with Lycra®. One of the newest innovations in spandex is black Lycra®, used in a new line of La Perla undergarments for women. Black Lycra® is naturally black, making for an extremely intense and uniform black fabric that resists fading.

Its elastic properties allow spandex to be a fiber now uncorseted by convention. In the future, Heslep expects to see spandex jump to the upholstery market for stylish

furniture. It already has found its way into the auto market where spandex allows door panel fabrics to stretch and adhere tightly to the door. Kirkwood says consumers can soon expect to see more Lycra spandex incorporated into natural and man-made leather shoes for greater comfort. And in the near future, more resilient spandex sports shoes may be in the offing as well as mattress-hugging spandex bed sheets.

### **2.1.7 Garment sizing**

Everything concerning pattern marking and grading starts with sizes and measurements. Clothing has to be made so that it fits the size and the shape of the body as well as possible. The size charts provide vital information which enables manufacturers to select and cater for specific areas of the population. It is obvious that whole population cannot be covered by a single manufacturer. <sup>(9)</sup>

In describing garment sizes the standard size labeling systems developed in Germany, Austria, Hungary and the USA have similarities. Garment sizes are indicated by arbitrary numbers, garment sizes are made for two or three height groups - petite (or short) regular and tall height and garment sizes are defined by three key dimensions - bust, waist and hip measurements. The need for having a systematic and scientific system for measuring and classifying human bodies in India for the purpose of developing a sizing system for garment was characterized by unprecedented retail growth.

As the masses start frequenting the "Malls" for their clothing requirements, they are becoming aware of the "fit" or rather the "lack of it" that the various brands offer. Fit has been cited as one of the major criteria that determine the purchase decisions for clothing. In India, we do not have even a primitive garment sizing system in place is, due to the traditional Indian garments comprised primarily of draped wear and whatever little stitching was required, could be catered to by the local tailor. We neither had organized retailing set ups and nor a fashion conscious or a fit conscious population. Thus the need was never felt for a readymade garment sizing system.

Textile Technology Department at IIT Delhi has been involved in research in the area of garment sizing for the past eight years. Survey was conducted manually in various educational institutions, following the ASTM methods D6240. Based on the understanding of the complexities in measurements, a special algorithm was

developed to locate the most prominent sizes existing in any given population. The anthropometric data sets generated have been analyzed through the software and sizes had been generated for various garment categories such as shirts, trousers and jackets etc. Fit trials were conducted with ITC Wills which is the industry partner to the project. The size charts obtained were compared with size charts of ITC limited. It was found that the predicted sizes were very close to what ITC was using. Fit trials yielded satisfactory fit for ITC Will's brand "Miss Players" tops.<sup>(73)</sup>

The measurement is association of numbers with physical quantities and so the earliest forms of measurement constitute the first steps towards mathematics. Once the step of associating numbers with physical objects has been made, it becomes possible to compare the objects by comparing the associated numbers. This leads to the development of methods of working with numbers.<sup>(62)</sup>

Only basic body measurements are needed to determine garment pattern type and size. The subject needs to wear proper undergarments and shoes when measuring. Also, the tape measure is held snugly and firmly (not tightly) against the body of the subject and is always parallel to the floor for circumference measurements.<sup>(63)</sup>

When sizing sweaters, the fit is based on actual chest/bust measurements, plus ease (additional inches or centimeters). The chart entitled "Fit" recommends the amount of ease to add to body measurements if you prefer a close-fitting garment, an oversized garment, or something in-between.

Both the fit and length charts are simply guidelines. For individual body differences, changes can be made in body and sleeve lengths when appropriate. However, consideration must be given to the project pattern. Certain sizing changes may alter the appearance of a garment.<sup>(64)</sup>

The metric system is an international decimalized system of measurement. France was first to adopt a metric system, in 1799, and a metric system is now the official system of measurement, used in almost every country in the world. The United States is the only industrialized country that has not defined a metric system as its official system of measurement, although the use of a metric system has been sanctioned for use there since 1866.<sup>(65)</sup>

Body Measurements - Metric System

Girls'/Girls' Plus - For the growing girl who has not yet begun to mature. Girls' Plus are designed for girl's over the average weight for their age and height.

Sizes	Girls						Girls' Plus					
	7	8	10	12	14	16	8 1/2	10 1/2	12 1/2	14 1/2	16 1/2	
Chest	66	69	73	76	81	87	76	80	84	88	92	cm
Waist	58	60	62	65	67	70	71	74	76	79	81	"
Hip	69	71	76	81	87	92	84	88	92	96	96	"
Back Waist Length	29.5	31	32.5	34.5	36	38	32	34	35.5	37.5	39.5	"
Approx. Height	127	132	142	149	155	156	132	142	149	155	161	"

Junior

Sizes	3/4	5/6	7/8	9/10	11/12	13/14	15/16	17/18	19/20	21/22	23/24	
Bust	71	73.5	77.5	81.5	85	89	92.5	98	103	108	113	cm
Waist	56	58.5	61	63.5	66	68.5	71	75	78.5	85	90	"
Hip-7" below waist	78.5	81.5	85	89	92.5	96.5	100.5	106	111	116	121	"
Back Waist Length	34.5	35.5	37	38	39	40	41	42	42.5	43	43.5	"

Misses'/Miss Petite - For well-proportioned, developed figures.

Misses' about 5' 5" to 5' 6" without shoes. Miss Petite under 5' 4" without shoes.

Sizes	4	6	8	10	12	14	16	18	20	22	24	26	
Sizes-European	30	32	34	36	38	40	42	44	46	48	50	52	
Bust	75	78	80	83	87	92	97	102	107	112	117	122	cm

Waist	56	58	61	64	67	71	76	81	87	94	99	106	"
Hip-9" below waist	80	83	85	88	92	97	102	107	112	117	122	127	"
Back Waist Length	38.5	39.5	40	40.5	41.5	42	42.5	43	44	44	44.5	44.5	"
Petite-Back Waist Length	36	37	37.5	38	38.5	39.5	40	40.5	41.5	41.5	42	42	"

Women's/Women's Petite - For the larger, more fully mature figures.

Women's' about 5' 5" to 5' 6" without shoes. Women's Petite under 5' 4" without shoes.

Sizes	18W	20W	22W	24W	26W	28W	30W	32W	
Sizes-European	44	46	48	50	52	54	56	58	
Bust	102	107	112	117	122	127	132	137	cm
Waist	84	89	94	99	105	112	118	124	"
Hip-9" below waist	107	112	117	122	127	132	137	142	"
Back Waist Length	43	44	44	44.5	45	45	45.5	46	"
Petite-Back Waist Length	40.5	41.5	41.5	42	42	42.5	42.5	43	"

Source: <http://www.allsewnup.org/measurement-metric.htm>

Palande L, in her article mentions that Clothes, accessories and makeup enhance your beauty only when you have a perfect body. Excessive weight, abnormal fat deposition not only hampers your looks but also lead to several health problems. It is a good sign that more and more people are becoming health conscious. 'Calorie' has become a buzzword in the society. Overweight people are always found looking for an easy weight loss diet. Not only women but men are also crazy about perfect body shape. Men are interested in achieving '6-pack abs' while women are interested in achieving

an 'hourglass shaped body'; where the width of the bust is almost similar to that of the hips (with an amazingly narrow waist).

Every woman cannot have the ideal body measurement, 36"-24"-36". But while trying to look more attractive, you should opt for healthy weight loss or weight gain. Your height, weight, amount of fat and distribution of fat determine whether you would look slim and sexy. Those who are interested in getting perfect curves at perfect places may refer to the body measurement chart for women, given below. Before that, here is some important information on 'the normal body-fat percentage for women'.

It is good to refer to a body measurement chart for women; but you should be happy with yourself, if you are healthy. There is no need to follow someone else to set your standard of beauty. Attractiveness depends only partly on the appearance. No matter how pretty and skinny you are, if you don't have a beautiful mind, no one would be happy in your company. There is no hard and fast rule about the perfect body measurement for women. For a man, who has eyes to see, a skinny or fat girl can be just as breathtakingly beautiful as a popular model. Women want a perfect shape because it gives them great satisfaction. But being healthy is more important than looking gorgeous.<sup>(67)</sup>

Today majority of the population is looking forward towards fashionable clothes but those which give them comfort, stretch and flexibility. Easy care and aesthetically satisfying fabrics are very much in production and well accepted by the consumers.

Stretch has fairly obvious impact on comfort, adding flexibility and freedom of movement. Garments have been linked to a second skin. Human skin is highly extensible and reverts back to its original position once stress is removed. It expands and contracts depending upon ambient temperature to protect body from temperature changes. It stretches depending upon dictates of the movement of the limbs and joints. Skin can stretch from 15 to 50%. Woven fabrics needed to be designed with specialized skills for cuts and styles to attain the level of comfort yet not giving satisfactory results especially casual and sportswear. Hence, initially textured weft knitted fabric was used in sportswear. The next development was lying in or plaiting on Elastomeric component in the garment which improved considerably stretch and

recovery characteristics of the sportswear and now found in every clothing item where comfort is the matter of concern.

The structural characteristics of knitted fabrics enhance the comfort, which is felt when garments made from such fabrics are worn. Knitted fabrics made from conventional fibers are owing to their knitted structure, more elastic than woven ones made from the same materials.

The knitted fabric has an edge over the woven fabrics by way of more comfort. Knitted fabrics drawbacks in patterning and designing, intricacies, losing the form etc. The technological development significantly changed the scenario to overcome these drawbacks. Also production of multihead, multifeeder, electronically patterned knitting machines contributed further an added advantage. As a fabric formation technique knitting was fastest and cheapest. Knitted clothes catching the mind and hand in the fabric fashion designing. He also describe that today knitted fabric has taken a coveted place in sportswear, leg wear, hand gloves, inner garments etc. and non-replaceable by other type of fabric.

The properties of cotton are limited due to its natural origins, and therefore Elastane is increasingly used to impart a great level of stretch and more dimensional recovery. Its slight stretch would add to the garment's comfort and resistance to wrinkling. It can be added lengthwise, crosswise or both directions in both woven and knits. Since stretch and elastic recovery are of such importance in fabrics, study of these properties is greatly needed. The results of such evaluations would be useful to create varieties of garments.

In considering the question of 'sizes', it is important to differentiate between those based on body measurements and those based on final sizes of the garment. The two are frequently confused, creating difficulties both in the production and in the sale of ready to wear clothing. It is the cutters responsibility to know how to produce a garment to fit each size in keeping with style and current fashion. The modern trend is for the 'size' to be more directly related to a body measurement (The Bust, Hips, Waist or Height) responsibility or the actual size or fit of the garment being left to the skill and judgment of the cutter.<sup>(32)</sup>

Anthropometry as one of anthropology methods is concerned with the measurements of the human body and determining the relationship of the size and proportion of the human body. Garment and footwear designation systems (HRN) are of general interest for the manufacturers, consumers and the entire population. There are no unique world's garment and footwear size labeling systems, but each country prescribes them based on anthropometric measurements taken, and size systems developed and established in different European countries differ from each other.<sup>(47)</sup>

## **2.2 Research Review**

### **2.2.1 Researches related to manufacturing with Lycra and related properties**

Today the textile industry is concentrating on giving new characteristics to natural fibres, improving manmade fibres, and blending the results. The impact of inter fibre competition has changed the character of textile production beyond all resemblance to historical fact. As one reviews conditions in the textile industry, it is evident that cotton continues to occupy first place in the market. The rapid advance of manmade fibres has placed them second to cotton in importance for fabric uses.<sup>(28)</sup>

**Kraemer (2002)** studied the impact of lycra power garments on the performance levels and this study was sponsored by Dupont from 1991 – 1995. A series of tests were administered in highly controlled laboratory conditions that represented the span of fatigue types experienced by an athlete when involved in sports or recreational activities. Before and after creating the fatigue, the athlete's ability to produce power was examined. The study revealed that all types of fatigue (strength, endurance and power) can be significantly reduced by wearing Lycra power apparel.<sup>(75)</sup>

**Parmar M. (2002)** has described the comfort in the fabric under high activity condition, and explained that absorption of the sweat followed by wicking and evaporation aids comfort. An unconventional way to create comfort has been tried by using a different type of yarn comprising two component fibres, defined as bi-component yarn. The fabric had been knitted and then subjected to washing so one of the soluble component in the yarn, gets removed, thus making the yarn in the fabric lighter, bulkier and softer.

After removal of water - soluble compound, from the fabric showed greater advantages over 100% cotton yarn knitted fabric in terms of absorbency, light weight

and softer feeling. Since the fabric is costlier than 100% cotton fabric, the cost of water soluble material would also be involved in this fabric.

Since the mid-1970s, change has rocked textile and apparel markets, because of the impact of Third World Labor costs and forces unleashed by the Baby Boomer social revolution. The consumer and the fibre industry believe that additional changes driven by incorporating elastomeric fibres into new lifestyle clothing.

The comfort has been an inherent feature of knitted textiles. That is why the knitted fabrics have been mostly in use for inner garment and the wears of delicate use like that of ladies and infant dress materials. The major factors responsible for creating comfort are: the softness; ability to absorb moisture; air permeability; the draping properties; the handle of the fabric; dissipation of heat and insulating properties.<sup>(34)</sup>

**Goswami B.C., Mantindale J.G. & Scardina F.L. (1977)** mentioned that aesthetic appearance is one of the most important criteria used by consumers in judging total wear performance of clothing. The appearance of a garment deteriorates during wear, often without suffering any structural damage. Garment bagging is a typical example of this phenomenon, which is a kind of three dimensional residual deformations that causes dissatisfaction. Besides this factor, clothing comfort is also quite important. To prevent deformation and to reduce bagging and aftermath effects of dimensional changes in different parts of the body, extendable and high elastic recovery fabrics have been introduced to the textile market. In recent years, yarns containing elastane have been used to increase the stretch properties of fabrics. As elastic fabrics can stretch far more than normal fabrics, they are preferred in daily clothes as an attempt to provide comfort and fitting properties. Stretch fabrics involve comfort control, easier movement in shape wear and foundations as well as more fashionable silhouette possible.

Elastic core-spun yarns are mostly used to obtain stretch fabrics. In these yarns, there is an elastomeric filament in the core and around it, where staple fibres are located. Consequently, the resultant fabric has all the characteristics of the predominant staple fibres together with the advantages of stretch and recovery.<sup>(12)</sup>

### 2.2.2 Wet processing and effects on properties

**Gargi M. (1980)** studied the effect of laundering on some physical properties of rib knitted fabrics and the study of surface change by scanning electron microscope. The dimensional stability and biaxial stress strain and growth, pilling and abrasion characteristics of knitted fabrics of pure cotton, Acrylic and polypropylene were used. It was found that pure cotton fabrics had low shrinkage value than Acrylic and propylene fabrics. Repeated washing stabilizes them. Analysis of stress strain data revealed that irrespective of fibre content of the fabric, all the samples showed a decrease in stress required as the number of landering increased, both in wale and course direction, Recovery after 15% strain was 100 percent for all the fabrics. All the fabrics exhibited 4 to 8 percent of growth at 30 percent strain for 24 hours in wale and course directions. The fabrics were found to be abrasion resistant least damage was caused to polypropylene compared to cotton and acrylic. Pilling results showed that polypropylene showed maximum pills followed by Acrylic and cotton.<sup>(23)</sup>

**PavkoCudena, A., Srdjakband, M., & Pelkoc, H. (2000)** mentioned in their study that the shrinkage of knitted fabrics significantly increases with the introduction of home laundering and tumble drying. The deformation caused by the mechanical forces can be reduced by appropriate relaxation. The quality requirement of knitted fabrics becomes highly demanding in terms of appearance and performance. In response to the demand, the fabric producers were inspired to develop a rich source of materials using a variety of yarn with Lycra for stretch and recovery.

Area density is a basic parameter defining knitted fabric offer. It is determined by both yarn and knitted fabric parameters on one hand and knitting and after treatment process parameters on the other. The objective of the investigation was to optimize the area density of a cotton/lycra plain knitted fabric and simultaneously examine the possible change of its performance properties like shrinking and laundering and elastic properties: breaking extension, maximum extension at cyclic loading up to defined load/extension and residual extension were assessed. The result of the study showed that area density of the knitted fabrics was reduced according to the optimization of knitting process parameters. Performance properties like shrinking at laundering and maximum extension were improved. It was suggested by the authors

that objective elastic properties measurement of knitted fabrics should be developed for uniaxial cyclic loading.<sup>(35)</sup>

**Mukhopadhyay et al (2003)** studied the effect of Lycra filament and full relaxation on the extension at peak load, immediate recovery, delayed recovery, permanent set and resiliency of cotton – Lycra blended knitted fabric. The study revealed for Lycra blended fabric, the immediate recovery, extension and resiliency are higher but delayed recovery and permanent set are lower than those of 100% cotton fabric. Effect of full relaxation treatment is found to be useful in case of all cotton fabric. On the application of external load, both lycra and non-lycra fabrics shows higher extension at peak load along course direction. However, the bias direction of 100% cotton fabric shows significantly higher immediately recovery and resiliency but lower delayed recovery and permanent set. Laundering reduces the extension at peak load, immediate recovery and permanent set become higher.<sup>(29)</sup>

**Thangamani, K. (2002)** studied shrinkage behaviour of knitted fabrics on repeated washing on seven different types of knitted fabrics – Single jersey, Interlock 1x1 Rib, 2x2 Derby Rib, Flat back rib, Locknit, Airtex. The fabric samples were subjected to 5 wash cycles, with benchmarks in the form of a square of dimension 25 x 25 cm. The samples were treated for 45 minutes at a temperature of 40°C in an IFB washing machine. Then they were dried in a hot air over until all the moisture was removed, allowed to cool and relax. After this the distance between the respective benchmarks was measured and tabulated. The process was repeated for another four times.

The results of shrinkage behaviour of different fabrics in repeated washings were as followed. The single jersey fabric shrinks for the first wash and the washing increases it tends to expand and again shrink. The interlock fabric shrinks for the first three washing and it expands in subsequent washing. The 1:1 Rib fabric for the first three washing elongates and shrinks in the fourth wash and again elongates in the fifth wash. The percentage of shrinkage gets reduced and moves towards a staple position in repeated washing for the 2x2 Derby Rib fabric. In repeated washings the Flat Back Rib Fabrics alternate between shrinkage and elongation. The shrinkage of the lock knit fabric for the first two washes remain near zero and start shrinking for the third and fourth wash. The Airtex fabric shrinks in the first four washes and for the fifth wash it expands.<sup>(46)</sup>

### **2.2.3 Blending Lycra with other fibers for end use and their properties**

Lycra is a manmade elastic fibre invented and produced by DuPont. Its remarkable properties of stretch and recovery enhance all fabrics and garments in which it is used, adding easy comfort and freedom of movement and improving fit shape retention, drape and crease recovery.

All types of hosiery are softer, smoother fitting and more durable thanks to Lycra®. The elasticity that Lycra® contributes to achieve sportswear allow it to cling aerodynamically close to the body without restricting movement. Lycra in women garments improves mobility and drape, and helps shed wrinkles. Knits with Lycra® keep their shape through repeated wearing. In short, a little bit of Lycra® makes all types of apparel fit better, feel better, look better.

The popularity of knitted fabrics have grown tremendously within recent years because the growth in consumer demand for stretchable, snug-fitting fabrics, particularly in the greatly expanding areas of sportswear and other casual wearing apparel. The structural characteristics of knitted fabrics enhance the comfort, which is felt when garments made from such fabrics are worn. Knitted fabrics made from conventional fibres are, owing to their knitted structure, more elastic than the woven ones made from the same materials.

The power of recovery in single jersey fabrics that have been stretched is generally inadequate, and therefore spandex is increasingly used to impart a greater level of stretch and more dimensional recovery than can be achieved with cotton alone. The use of spandex has resulted in fabrics that fit better on the body like a second skin and have good shape retention without any deformation throughout the life of the garment.

Since stretch and elastic recovery are of such importance in fabrics, evaluation of these properties for fabrics of various constructions made of different kinds of garments is greatly needed. The results of such evaluations would be useful to create varieties of fabrics for special purpose. This would further be useful for construction of garments to fit the range of sizes with satisfactory fit, style and comfort properties.

The aesthetically pleasing appearance, loose elastic structure, comfort and softness of knits when compared to rigid woven, make them ideal to be used in sportswear, innerwear, sweaters, casual wear, fashion apparel etc. Generally the knits have problems of dimension stability and spirality due to factors such as fibre character, yarn structure, knit patterns, loose structure, extent of stress applied, type of laundering, etc. The amount of stretch and the elastic recovery, also called 'recoverable stretch', determines the suitability of knitted fabrics for specific uses. For example a fabric that stretches little, is a poor selection for a slip on sweater. On the other hand, one of minimum stretch but high recovery is desirable for gloves.

Clothing physiology is the mechanism of interactions between the human body and its clothing system and it aims to provide information on the physiological properties of clothing. Clothing physiology is expressed in terms of comfort, performance, capability and health of the wearer. The clothing is said to be physiologically right when it functions correctly while physical activity is taking place. Functionally correct clothing is only possible when there is a correct interaction of fibre, spinning, weaving or knitting parameters, fabric density, thickness and weight, coloration and finish, garment fit and making up techniques.

Stretch has fairly obvious impact on comfort, adding flexibility and freedom of movement. Scientists have learned much about the relationship between body comfort and garment shape retention by studying the skin as it flexes and stretches. Their studies helped a lot to decide how much stretch is right for specific garments and certain body needs. For examples the waist band on tights has to stretch over the hips and then instantly recover to fit a smaller waist without sagging.

**Hansen and Fletcher (1949)** studied on evaluation properties of knitted fabrics and found that cotton and rayon materials decreased in recovery with an increase in strain, & for large strains had least recovery. It was found that time factor played an important role in elastic recovery for cotton, nylon, rayon and cool were 26, 19, 26 and 48 percent whereas the combined instantaneous and delayed recoveries were 58, 59, 55 and 80 percent respectively. Further the results indicated that delayed recovery of nylon materials was twice than that of the instantaneous recovery of the same material.<sup>(15)</sup>

**Mundan (1962)** studied the relationship of dimensional property of the geometry of plain knit fabrics various loops models were studied the found that there was a specific relationship between stitch density and stitch length which was independent of fabric openness. He further stated that the course and wale spacing are directly proportional to the stitch length. It was found that stitch density and dimensions of a fabric in the relaxed state are unaffected by the change in yarn count if the stitch length remains constant. Fabric dimension may be affected by change in yarn count owing to its effect on the extensional properties of the fabric. After relaxation the fabric will recover to similar dimensions if knitted to the same stitch length. <sup>(30)</sup>

A study on the evaluation of elastic recovery of cotton knitted fabrics was conducted by **Robert and Fletcher (1964)**. They found that elongation of these fabrics varied to a great extent. The elongation varied from 3-6 percent plain knit lengthwise, 3-45 percent double knit lengthwise, 3 – 235 percent plain knit widthwise and 6-156 percent double knit widthwise. The elastic recovery varied from plain knit lengthwise, 100-56 percent double knit lengthwise, 100-55 percent plain knit widthwise and 100-30 percent double knit widthwise. The growth recovery was found to be 0 to 106 percent plain knit and 0 to 111 percent double knit. Plain knit had more elongation and growth as compared to double knit. The growth after 30 seconds or relaxation was observed to be 36 percent and plain knit stretched more under load and after the load was released exhibited more growth than the double knit. <sup>(40)</sup>

**Petter Poper (1966)** has also studied the theoretical behaviour of knitted fabrics subjected to biaxial stresses. His work has show that biaxial deformation of textile material depends to a greater extent on fabric geometry as well as on the fiber properties. The “Structural” behavior is superimposed on the material properties of the fibers where an actual fabric is stressed and in many cases, the structural effect can predominate. It has shown that the plain knit fabric can deform considerably without any elongation of the component yarns. The fabric when extended, will reach a limiting extension in either direction due to yarn jamming. The main conclusion was that knitted fabric develops a unique mechanical behaviour from its geometry and ability to deform by inter yarn slipping. This structural behaviour of the yarns gives the final behaviour of the fabric. <sup>(37)</sup>

**Elder and Somashekar (1975)** had made an attempt to study the bending and recovery properties of cotton plain knitted fabric by using Shirley Bending Hysteresis Tester. They had considered parameters like flexural rigidity and bending recovery i.e., the degree of flat set separately for wales and courses. IT has shown that relaxation causes a ten fold reduction in inter yarn forces and couples. The effect was noted for fiber relaxation in yarn structure. <sup>(11)</sup>

**Brain et al (1975)** studied the biaxial deformation characteristics of plain knit fabrics. They found when stretching proceeds, yarn strengthening occurs. During the straightening stages the knitted fabric deforms in such a way that the yarn in the cross over region start sliding past one another. Friction causes tension in the wide direction, which may be greater or less than the tension in the course direction, depending on which way sliding occurs. <sup>(7)</sup>

**Mahirskaris (1978)** studied the growth and elastic recovery properties of plain and rib knitted fabrics. The immediate elastic recovery and permanent growth were determined by modifying the ASTM method D 1775-60. One plain knit and three rib knit fabrics (cotton, nylon and polyester) were selected. The results revealed that among all the fabric plain knit cotton fabric showed 100% stretch ability with severe curling effect and having poor elastic recovery. The study also concluded that rib have a tendency to stretch more in course wise direction than in wale wise direction. Rib fabrics showed considerable loss in stress required with increase of frequency the nylon fabric showed delayed elastic recovery and plain cotton showed very low elastic recovery and growth. <sup>(22)</sup>

**Bains, M. (1979)** studied the stress strain characteristics of woven and knitted fabrics subjected to uniaxial and biaxial stresses. Elastic recovery behavior of both woven fabrics of pure cotton, nylon and polyester blends and three knitted fabrics of cotton and polyester of plain and 1x1 rib knit were used for the study. For measurement of stress strain characteristics, an instrument was constructed with required modification. The woven and knitted fabrics were subjected to uniaxial and biaxial stress. It was concluded that all fabrics subjected to uniaxial stress, showed extension in the variable load and contraction in the weft direction or vice versa. It was observed that higher the extension of the samples, greater was the contraction. In knits, wasting was observed in both wale and course direction. <sup>(4)</sup>

**Kunzru, V. (1982)** studied hand knitting sample of different patterns and their applications in household articles. The study was undertaken to find out the 'tension measurement' the amount of yarn in length and weight required for different patterns when knitted on different needles. For the study eight commonly used knitted patterns were selected for the tension measurement, yarn length and weight calculations. Out of eight patterns six were selected for the measurement of elastic properties. An instrument was fabricated on the basis of instrument used by Mahiskar N. <sup>(22)</sup> to determine elongation of the knitted samples. The immediate and delayed elastic recovery was also determined. It was found that there was an increase in tension with an increase in the needle size for every knitted pattern. Results of elongation showed that elongation does not depend upon the individual 'knit' or 'purl' stitch, but upon the placement of these stitches in combination, in various patterns.

It was also observed that the pattern which elongates less recovery most. Curling was observed in patterns where the two sides comprise of different stitches. <sup>(19)</sup>

**Srivastava (1983)** studied the elastic characteristics of knitted fabrics, with and without seam on 100 percent polyester was taken. The extension and elastic recovery of fabrics with seam and without seam were determined with the help of bulging tester. The percent extension and percent elastic recovery after 5 minutes and 30 min. at various loads were calculated.

The analysis of the work was that elastic recovery was more or less same in the knitted fabrics due to the similarity in knitting structure. With the introduction of seam in sample at various loads, extension ranged from 58 – 94 percent and elastic recovery was 97 to 99 percent. In fabrics with seam and without seam it was found that, extension was reduced due to the seam stitches hundred the extension of knitted fabrics. <sup>(44)</sup>

**Mehta I. (1990)** studied the stretch and recovery characteristics in woven and knitted fabrics. The fabrics were cotton blended in plain twill weave and plain knit, interlock, honey comb and fleece fabrics. The stretch and recovery of woven and knitted fabrics were determined using the Scott tensile tester at 5, 10, 15 nos. load and the bulging tester using 1 kg load. The percent stretch and percent recovery were calculated.

Aesthetic appeal for dress in combination of knitted and woven fabrics was judged by observers with help of snaps.

It was concluded that knitted fabric had good stretch and recovery than woven. Knitted and woven fabrics in combination fabric form also had a good recovery. It was found that the image of knitted being used for only as sportswear changed and they were much accepted as evening wear and casual wear. <sup>(26)</sup>

**Marmarali (2003)** conducted a study on the dimensional and physical properties of cotton / spandex single jersey fabrics and the results were compared to 100% cotton knitted fabrics. The loop length and amount of spandex were used to determine the dimensions and properties of the knits. Cotton / spandex in every course or in alternating courses classified as full plating and half plating respectively. The study revealed that the dimensional and physical properties of cotton and cotton / spandex single jersey fabrics are affected by the amount of spandex in the fabric and the loop length. The course and wale spacing values of cotton / spandex samples are less because the fabrics tend to be tighter. The weight and thickness of full plating cotton / spandex fabrics are higher, but air permeability, pilling grades, and the degree of spirality are lower than half plating cotton / spandex and cotton fabric respectively. Also the dimensional variations widthwise for 100% cotton samples are higher, while the lengthwise variations for the same fabrics are less after relaxation. <sup>(25)</sup>

**Nair S. (2004)** studied the 'Growth, growth recovery and cyclic snap stretch characteristics of cotton Lycra spandex fabric'. The study was carried out with 100% cotton and 96 x 4% cotton / Lycra fabrics of woven category and 100% cotton, 96 x 4% and 94 x 6% cotton / Lycra single jersey fabrics knitted categories. The fabrics were tested for growth and growth recovery characteristics, effect of dry heat, effect of light and effect of cyclic load with snap tester. It was found from the study that the fabrics 100% did not permanent set in either woven or knitted structure, but with Lycra in 4% and 6% both woven and knitted samples showed permanent set of 1 to 1.25%. Effect of dry heat attributed to degradation of the polymer chain of Lycra leading to loss in tensile strength and loss in stiffness. The results of cyclic snap testing showed formation of surface bulges and folds at the knee joint on 30% stretch was influenced by the percentage of Lycra present in the fabric. The cyclic load did

not show any bulges upto 1000 cycles, further upto 2000 cycles only the folds appeared showing good recovery of fabrics with Lycra.<sup>(31)</sup>

**Sabria, G. et al (2006)** studied influence of sewing parameters upon the tensile behaviour of textile assembly. As per them the stitch line is expected to play an important role in the tensile behaviour of the assembly. In fact, the deformation of the assembly is a mixture of deformation of the fabric and that of the seam. In order to study the seam behaviour, an extension load curve for the stitch line was established. The results of the study were expressed through the description of load and extension curve followed by analysis of rupture of fabric or the seam. The visual analysis of seam slippage show that the displacement of yarns made it possible to bring out two major phenomena occurring before the rupture of assembly: Contracting of seam or Seam slippage. Contracting of seam has always induced the breaking of the sewing thread without any damage of the sample, whereas when seam slippage occurs, the seam is still intact but yarns in the fabric pull out of the seam from the edge, sewing thread ruptured leaving holes due to yarn slippage, damage of the fabric along the stitch line. Further comparison of warp, weft and bias direction of the seam that were introduced in terms of thread breakage or seam slippage was done.<sup>(41)</sup>

**Baghaei, M., Shanbeh, M., & Ghareaghaji, A.A, (2010)** studied Effect of tensile fatigue cyclic loads on bagging deformation of elastic woven fabrics. Eight different kinds of core-spun yarn, which contain 44.4 dtex/4f spandex filament as the core and cotton fibres as the sheath to spin 19.7 tex elastic core-spun yarn, were produced. The yarns were used as weft and all the fabrics were produced with plain structure using the Rapiere weaving machine. The instrument for tensile fatigue cyclic loading was designed with two sensors control the initial and final position moveable clamps. The fabric samples were fatigued upto 1000 and 2000 cyclic loads with frequency of 9.8 Hz. According to this method, samples were extended upto 90% of their elongation at break and returned to initial position. These operations were repeated till the proposed number of cyclic loads. After applying cyclic loads on samples, bagging tests were carried out on samples. The results of the study were concerned in weft direction as the elastane yarn was used in the weft direction. The comparative evaluation of the results showed that the bagging fatigue of woven samples depends on the draw ratio of core part and twist factor of elastic core spun yarns. Number of cyclic loads was

found to be effective 1000 cycles but no specific trend was observed in fatigue after 2000 tensile fatigue cyclic loads. The stretching properties of fabrics supported the fatigue behaviour of them under tensile fatigue cyclic loads. <sup>(3)</sup>

**Zhou, j. Li Yi, Jimmy Lam and Cao Xuyong, (2010)** studied 'The Poisson Ratio and Modulus of Elastic knitted Fabrics'. The fabrics used in the experiments were full plating single jersey knitted fabrics with yarn 75D/72f Coolmax and plating yarn 30D and 40D XLA elastic fibre. Six samples were obtained with different elastic constants by altering the elastic yarn thickness and input tension. The fabric samples were tested on INSTRON 4411 tensile test machine (CRE type) according to ASTM D 4963-96 for uniaxial tensile test and for strip biaxial tensile test a Karvabata KES-G2-SBI tester was used.

The results of the study showed that the new method for the Poisson's ratio and Elastic modulus of elastic knitted fabric was proposed based on the orthotropic theory and strip biaxial tensile test. There were linear elastic behaviour and significant poisson effect in the elastic knitted fabric due to its unique stitch structure. The biaxial method measured the fabric Poisson's ratio and elastic modulus simultaneously. It is preferable to simulate the real application sate of elastic knitted fabrics, for example, a tight – fit garment in wearing condition. This research work provided an effective approach to investigate the factors that affect the elastic constants of elastic knitted fabrics. <sup>(52)</sup>