INVESTIGATION OF DIMENSIONAL STABILITY OF KNITTED FABRICS

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ABSTRACT

INVESTIGATION OF DIMENSIONAL STABILITY OF KNITTED FABRICS

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Knitting is the most frequently used method of fabric construction. The popularity of knitting has grown tremendously within recent years because of the increased versatility of techniques, the adaptability of the new manmade fibers, and the growth in consumer demand for wrinkle-resistant, stretchable, snug fitting fabrics, particularly in the greatly expanding areas of sportswear and other casual wearing apparel. Today, the usage of knitted fabrics ranges from hosiery, underwear, sweaters, slacks, suits, and coats, to rugs and other home furnishing. However, some serious problems were appeared within. One of the most important problems is dimensional deformation on fabrics after laundering process.

In this study, the dimensional stability, breaking strength and breaking elongation tests made on knitted fabrics, which were made of different knit structure. In these tests some parameters such as type of fiber, yarn counts, yarn structure(ring/rotor), plied yarns and fabric structure were taken into account after subsequent washing and drying processes and the results were compared each other. From the test results it was clearly seen that fabrics which were made of synthetic yarns in comparison cotton yarns, double plied and coarser count yarns in comparison with single plied and fine count yarns, ring spun yarns in comparison with rotor spun yarns have better strength and fabric dimensional deformations with respect to the other test samples.

Key words: circular knitting, dimensional stability, shrinkage, quality control, knitting faults.

ÖZ

ÖRGÜ KUMAŞLARIN BOYUTSAL STABİLİTESİNİN ARAŞTIRILMASI

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Kumaş oluşturmada en fazla kullanılan method örmeciliktir. Son yıllarda çeşitli üretim tekniklerin artması, yeni sentetik elyafların kullanılması, ve müşteri taleplerinin büyümesi, buruşmazlık direnci, gerilebilme, vücudu saran esnek yapısı ile spor ve serbest zaman giysisi olarak tercih edilmesi ile birlikte örme kumaşların popülaritesi artmıştır. Bugün kullanılan örme kumaşlar, çorap, iç çamaşır, süveter, kazak, takım elbise, ceket, kilim ve diğer ev tekstillerinde kullanılmaktadır. Örgü kumaşların kullanımının yaygınlaşması bazı önemli sorunları da beraberinde getirmiştir. Bu problemlerin en önemlilerinden birisi, yıkama sonrası kumaşın orijinal boyutunu koruyamaması, boyutsal deformasyona uğramasıdır.

Bu çalışmada, farklı örgü yapısına sahip kumaşlar üzerinde, boyutsal stabilite, kopma mukavemeti ve kopma uzaması testleri yapılmıştır. Bu testlerde, elyaf tipi, iplik numarası, iplik yapısı (rotor/ring), iplik kat adedi ve örgü yapısı göz önüne alınarak, yıkama ve kurutma işlemleri sonrasında elde edilen sonuçlar birbiriyle karşılaştırılmıştır. Test sonuçları göstermiştir ki, sentetik karışımı kumaşların, pamuklu kumaşlara göre, çift kat ve kalın numara iplikten yapılmış kumaşların, tek kat ve ince numara iplikten yapılmış kumaşlara göre, ring ipliğinden yapılmış kumaşların, rotor ipliğinden yapılmış kumaşlara göre, boyutsal stabilitesinin daha iyi olduğu ve kopma mukavemet değerinin daha yüksek olduğu gözlenmiştir.

Anahtar kelimeler: yuvarlak örme, boyutsal stabilite, çekmezlik, kalite kontrol, örgü hataları.

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TABLE OF CONTENTS

CHAPTER 3

CHAPTER 4

CHAPTER 6

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1. Introduction

Knitting is a method of converting yarn into fabric by intermeshing loops, which are formed with the help of needles. There are two basic forms of knitting technology, weft and warp knitting. Hand knitting process is weft knitting, which can also be done by machine. In this process, work progresses widthwise, in a back and forth cycle. In each cycle, known as a course, a new row of stitches is formed. In each row there may be number of stitches depending upon the width of the fabric to be knitted. Each stitch of the row gets build-up intermeshing with the previously held stitches of the preceding row. The vertical row of stitches or chain of loops hanging vertically from the needles is wale. Weft knitted fabrics can be produced in either flat or tubular form. Weft knitted fabric is generally highly elastic and highly drapeable, two attributes, which make it suitable for a wide range of apparel applications. Weft knitted fabric is porous and comfortable both for outer garments and undergarments. In contrast, warp knitting, which is done by machine, the work progresses lengthwise, through the intermeshing of loops in the direction of wale. In this process all the loops on the knitting needles in the row remain in the knitting mode. The main advantage of warp knitted cloth is that, unlike weft knitted fabric, it is not easy to unravel. However, these fabrics are not as elastic as weft knitted fabrics[1].

Knitted fabric is formed by the interlocking of loops of yarn, which tend to stretch and confirm to the shape of the wearer. Again, the degree of stretch can be engineered by varying the knitted fabric structure to give the much desired properties for apparels like shape retention, wrinkle resistance and drapeability. So, people have started releasing the utility of knitted fabric cloth as under and outwear garments. It is also seen that percentage share of yarn consumption for knitting has become about 60% in advanced countries.

From ancient times, the art of hand knitting remained an occupation for women folk. Other than knitting many crafts are practiced today. Such as those, crocheting, making cloth toys and dolls, flower crafts, shell crafts, wood craft, candle making, decorative inlay and sculpting. In 1589, William Lee, a clergyman invented the first knitting machine in England. After this invention, in the 17th and 18th centuries the art of knitting was gradually taken over by guild organized cottage industry. Interestingly, the basic technology of the modern day knitting machines is similar to Lee's machine. Even the full-fashioned machine invented in 1864 by William Cotton of Leicestershire, England used the same bearded-spring needle, which was part of the original model of Lee. The art of knitting has come of age. From hand knitting to hand operated machines was a long way. Gradually it upgraded to power operated V-bed and circular knitting, and then it leapfrogged to microprocessor controlled machines. Now lately CAD/CAM has revolutionized the knitting industry[2,3].

1.2. Quality Control and Dimensional Stability

The quality of a garment is determined by the characteristics of each of its components from fiber to fabric to the very last finishing detail. Many properties help to determine fabric quality and consequently, the quality of apparel or other products in which the fabrics are used. Textile testing procedures are often used for quality control. Textile products are tested at various stages of production to assure quality processing and products. A common problem with woven and knitted textile products is development of dimensional change is after laundering. Dimensional changes, an element of fabric quality.

Dimensional stability refers to the extent to which a fabric retains its shape and size after being subjected to wear and maintenance. Two of the major concerns in the performance of textile products is shrinkage and skew. Shrinkage is the reduction in size of the fabric while skewing is the twisting or shifting of the fabric. Fabric construction, for example woven or knit, is a key factor in determining dimensional stability. To obtain the purpose of the dimensional stability of the knitted fabric:

a) Wearing comfort and fabric appearance.
b) Protect knitted fabrics original shape.
c) Unshrinkable of knitted fabrics.

d) Resistance to flexibility and loose.

Fabric shrinkage is a serious problem for knitwear, originating from dimensional changes in the fabric, particularly stitches. It has become even more prevalent in recent years due to the popularity of casual wear such as tights, pants, blouses, and sportswear. Shrinkage is a result of the combined effect of numerous factors such as relaxation, finishing, dyeing and effects of machinery. The significance of this problem has been investigated by several researchers, who focused mainly on the geometry and dimensional relations of knitted structures[4].

It is well known that weft knitted fabrics tend to undergo large changes in dimensions and are often prone to distortion upon repeated laundering. A large number of factors are responsible for causing these undesirable effects in knitted structures; these are all associated with the yarn, knitting, finishing and making-up of the fabrics. It is also a fact that consumers are becoming increasingly concerned and aware of fabric quality and expect higher standards of performance than ever before, even after a number of wash and dry cycles[5].

With the rising popularity of cotton greater demands for quality have been required as end-users have been become more aware of its negative properties, and therefore many studies have been reported on the geometry and dimensional properties of knitted fabrics produced from different kinds of yarns. Although the problem of knitted fabric shrinkage can be solved to some extend by replacing 100% cotton with a cotton/synthetic fiber blend yarn, the severity and longevity of pilling, in turn, greatly increases, and pilling has become a much more serious problem for the knitted apparel industry[6].

Many workers have investigated the dimensional behavior of knitted structures and the dependence final dimensions on spinning system, count number, raw material.

First observations are made on plain knitted fabrics because of basic structure later it's continued other fabrics. First systematic study is made on 1914 by Tompkins[7]. Loop density remain some and it is independent from fabric deformation.

Dutton is made researches on plain fabrics' big diameter. At the end, he determined quality and dimensions of plain fabrics dependent many factors like yarn type and winding of yarn, machine type and speed, storage condition of fabrics, temperature, moisture condition of yarn warehouse knitting mill and fabric warehouse, type of finishing, number of laundering process[8]. According to Dutton, dimensional changes of the fabrics are affected external forces during knitting, which is resulted fabric deformation. During the knitting process, the yarns forming the fabric are constantly under stress. As a result, the fabric on the machine is more distorted than its natural relaxed state. When the fabric is removed from the machine, it has time to relax and overcome these stresses, a form of relaxation that is easily recognizable by the changes in dimensions.

As Suh is noted, that a study of the shrinkage of plain knitted cotton fabrics, on based on the structural changes of the loop geometry due to yarn swelling and deswelling[9]. Shrinkage of a knitted fabric is determined by a number of factors, such as fiber characteristics, stitch length, machine gauge, yarn twist, knitting tension, washing and drying methods. However, as he explains, the factors most responsible for shrinkage are known to be the swelling of yarn and the relaxation of internal stress to which the yarns are subjected during the knitting process.

Rnamanik and Ajgaonkar are observed that plain fabrics physical and dimensional specifications which are made different proportion of cotton/viscose, cotton/polynosic, cotton/polyester blends samples are produced of different yarn counts[8]. At the result the most area shrinkage is seen fabrics which are made of 100% viscose when the proportion of modal raise, shrinkage ratio decrease. In cotton/polyester blends fabrics, adding 40% more polyester in blends is effected positively comparing 100% cotton fabrics. It is observed that 20/80 viscose/cotton or modal/cotton blends values, loop density, fabric weight area shrinkage values same with 100% cotton values.

Mackay, Anand, and Bishop are investigated acrylic, cotton, and wool rib knitwear fabrics have been subjected to several laundering cycles using a variety of washing and drying conditions[10]. The dimensional, mechanical, and tactile properties of new and washed fabrics are determined and evaluated using standard test procedures. This work are to examine the ways in which the conditions chosen for domestic laundering can effect the mechanical and sensory properties of knitted fabrics over a large number of wash cycles and to identify and damping aspects of the laundering process for individual fiber types. They establish the techniques for predictions the final, full relaxed dimensions of knitted fabrics. They identified some of the factors that lead to consumer dissatisfaction with the washing performance of these knits, and analyzed changes in fabric dimensions. They determined the full relaxed constant values for these fabrics and showed that they are influenced by fiber type, and they suggested that these values will enable knitters, dyers and finishers to predict and control with greater confidence the shrinkage behavior and final dimensions of rib knits constructed from cotton, wool, and acrylic yarns.

Quaynor, Nakajima, and Takahashi are studied deformation by laundering is investigated for single jersey and rib flat knit silk and cotton fabrics with yarns of varying linear densities and fabric tightness[11]. The fabrics are subjected to relaxation processes and an extended series of wash and tumble dry cycles. Statistical analysis of the experimental data reveal the effect of yarn types as well as linear density and tightness factor on the linear and area shrinkage behavior of silk as compared to cotton. Multiple washing and tumble-dry cycles result in an almost complete relaxation state especially for cotton. With cotton plain knits, shrinkage in laundering decreases with tightness, but with silk, the laundering process increases shrinkage with the fabric tightness. The area shrinkage of rib knits increases with fabric tightness in the case of cotton. With plain knits, cotton shrinks more than silk. With rib knits, the dimensional stability is good for cotton, while with silk there is a poor shape retention in the form of stretching. Experimental results have shown that, for silk, one laundering cycle after wet relaxation is required to bring the fabric to a fully relaxed state for both plain and rib knits.

Another study of Quaynor, Nakajima, and Takahashi, is on the effects of laundering and laundering temperatures on surface properties and dimensional stability are investigated for plain flat knit silks, cotton, and polyester fabrics with varying cover factors[12]. Changes in dimensional stability and surface properties with relaxation processes and laundering temperatures are clarified. The highest shrinkage is recorded with slackly knitted cotton at the highest temperature. There is a considerable effect of wet relaxation on dimensional stability as well as surface properties. The shrinkage with varying temperatures seems to depend on cover factor.

In Candan, Nergis and İridağ, research the dimensional and some physical properties of a series of plain jersey and lacoste fabrics made from both cotton ring and open-end spun yarns are investigated[13]. The results show that structural differences in the yarn ply a large part in determining the dimensions and behavior of these two fabric types. It is apparent that the amount of relaxation shrinkage occurring with open-end spun yarn is greater than that with ring spun yarn. Furthermore, open-end spun yarns tend to be weaker, which results in lower bursting strength, and the fabrics knitted from such yarns tend to pill more. Finally, so far as abrasion resistance is concerned, ring spun knits perform slightly better than open-end spun knits.

Candan and Önal, studied on the dimensional, pilling and abrasion properties of a series of plain jersey, lacoste, and two thread fleece fabrics made from cotton ring and open-end spun yarns as well as from blend yarns[14]. The results show that both structural differences and fiber type ply a large part in determining the dimensions of these fabrics. It is apparent that knits from blend yarns have a lower dimensional stability compared to fabrics from 100% cotton ring and open-end spun yarns. Findings for the two thread fleece fabrics suggest that the inlay yarns mainly govern their dimensional behavior in the widthwise direction. The dimensional behavior of the lacoste and two thread fleece fabrics after the laundering cycles reveals that further research to determine more appropriate washing regimes for these structures would be beneficial. The pilling rates of the samples indicate that unlike plain jersey fabrics, lacoste fabrics perform very well, and that in general, fabrics knitted from open-end and blend spun yarns have a lower propensity to pill.

Higgins et al. are observed factors during tumble drying that influence dimensional stability and distortion of cotton knitted fabrics[15]. In this study, the length and width shrinkages, skewness, spirality and moisture content of three weft knitted cotton structures, plain single jersey, interlock and lacoste, were determined at regular intervals during tumble drying. Significant length and width shrinkages occurred in all three structures with the amount of shrinkage increasing rapidly in plain single jersey and lacoste as their moisture contents fell below 30 percent. Distortion was less affected by tumble drying. An attempt was made to isolate the effects of heat and agitation during tumble drying. It has been demonstrated that similar patterns of shrinkage and distortion occur whether heat is applied during tumble drying or not. The tumbling action in a tumble drier has the greatest influence on the dimensional stability and distortion of weft knitted cotton fabrics.

Candan and Önal, studied on cotton and cotton/polyester blended weft knitted fabrics are prone to shrinkage during finishing process and customer usage. The effect of various fabric characteristics on the shrinkage behavior of weft knits is an important as that of the fiber characteristics[4]. Three different single jersey knits with varying fabric tightness, yarn types, and fiber blends are selected for their characteristics. The contribution of each characteristics to shrinkage behavior is presented statistically using an analysis of variance. The fabrics are subjected several laundering cycles followed by tumble drying. Double pique knits shrink less widthwise but more lengthwise than the other knit types. Yarn type and fiber blend have a relatively more significant contribution to fabric shrinkage lengthwise than widthwise. Knit loop formation is defined in each relaxation stage from dry relaxed to fully relaxed.

Marmaralı is researched the dimensional and physical properties of cotton/spandex single jersey fabrics are investigated and the results compared with fabrics knitted from cotton alone[16]. The loop length and amount of spandex are used to determine the dimensions and properties of the knits. It is apparent that as the amount of spandex increases, loop length values remain nearly the same and the course and wale spacing values decrease. Furthermore, because spandex-containing fabrics tend to be tighter, the weight and thickness of the fabrics are higher but air permeability, pilling grade, and spirality are lower.

1.3. Purpose of the Thesis

The aim of this study is to investigate dimensional stability, breaking strength and breaking elongations at of weft knitted fabrics which have different properties. The fabric properties of sample fabrics, are given below;

1) Type of fibers; cotton and cotton blends; cotton/acrylic, cotton/polyester fabrics are used in this study.
2) Structure of yarn; according to yarn production method rotor and ring yarns, which are single plied yarn and double plied yarn are used with different yarn numbers.

3) Knit structure; plain, lacoste, rib, fabrics are used.

Systematically the effect of the principal washing and drying variables on the dimensional stability and distortion of knitted fabrics are investigated. The fabrics are subjected to ten laundering cycles followed by tumble drying. Changes in the dimensions are fully measured after each processes. Also breaking strengths and breaking elongations are tested after each process.

1.4. Structure of Thesis

Chapter 2 includes the detail information about knitting technology, history of knitting, the difference between weft and warp knitting methods, basic knitted structures and their properties (plain knitted fabrics, rib knitted fabrics, purl knitted fabrics, interlock knitted fabrics). Then brief explanation about end uses of knitted fabrics, types of knitted loops (held loop, drop or press off stitch, tuck loops, float stitch, selvedge stitch), and also knitting needles were explained in this chapter.

In chapter 3, concept of quality and quality control methods were described. Therefore the detail information's about fabric quality control, standard test methods, properties of knitted fabrics are also given. Then brief explanation about fabric test methods (breaking strength, tensile strength, bursting strength, stretch and recovery, wrinkle recovery tester, elongation, snagging test methods, pilling test methods, abrasion resistance and dimensional stability) were given. Also the problems of knitted fabrics, garment quality factors were explained.

Chapter 4 includes detailed information about dimensional stability. The basic factors which affects dimensional stability laundering process (standard laundering process, dimensional change in home laundering) and other factors such as, water, temperature and drying were explained. Relaxation, shrinkage, purpose of the dimensional stability, testing methods for dimensional changes were given.

Chapter 5 is about the experimental studies. Fabric properties, standards, specimens preparing, test procedures, graphs of dimensional changes, breaking strength and breaking elongation were given in this chapter.

The conclusion of thesis and recommendation for further studies were given in chapter 6.

CHAPTER 2

PRINCIPLE OF KNITTING

2.1. Introduction

Knitting is the most common method of interlooping of manufacturing textile structures. Knitting technology comprises all processes that are required to produce knitted fabrics. A knitted fabric is a textile structure made by the interlooping of yarns. A yarn is an assembly of fibres of substantial length and relatively small cross-section, with or without twist. The exact origin of knitting is not known, but it is believed that knitting probably developed from the experience gained by knotting and twisting yarns[17].

The popularity of knitting has grown tremendously within recent years because of increased versatility of techniques, the adaptability of the many new manmade fibers and the growth in consumer demand for in the greatly expanding areas of sportswear and other casual wearing apparel[18].

The present knitting industry is based on the invention of William Lee, who succeeded in the mechanizations of the interlooping of yarns four hundred years ago. A marked development in this technology has taken place over the last fifty years. An immense number of new developments and improvements have continuously changed the state-of-the-art of this technology, and today knitted fabrics have found their way into almost every field of application of textiles. Some areas of their application include socks, stockings, underwear, pullovers, jackets, frocks, blouses, suits, winter overcoats, bed-sheets, pillowcases, baby clothes, curtains, carpets, upholstery materials, table cloths and artificial fur[19].

A new and rapidly developing trade in the knitting industry is the production of technical textiles and composites. New products are developed daily; in most cases knitted structures are replacing expensive, heavier and technically inferior constructions traditionally manufactured from other materials. Some interesting industrial applications are warp knitted sacks, high quality warp knitted flags, blood arteries, filter materials, geotextiles for road construction, tear resistant sails, floor coverings and 3-D knitted performs for composite components[20].

2.2. History of Knitting

The art of hand knitting has been practiced since thousands of years. How this art was learnt by ancient human is still a mystery and so is the country and time of its origin. However, some believe that this art originated in Persia. Others claim Israel, Jordan and Syria belt as its origin, and still others claim mountains of North Africa. Knitted socks discovered in Egyptian tombs have been dated between the 3rd and 6th centuries[21].

In the medieval Europe hand knitting was an important industry and had developed into an advanced craft by 16th century. From ancient times, the art of hand knitting remained an occupation for women folk. Originally knitting remained entirely confined to making socks and women's stockings. Earlier than this the leg and foot coverings were woven. Now they hand-knit all sort of garments, sweaters, cardigans, blouse and even skirts[22].

In 1589, in the reign of Quenen Elizabeth I, the Reverend William Lee, a curate of Calverton in Nottinghamshire, presented himself at the Court of the Queen with a request for Letters Pattent for his newly invented knitting machine[23].

After this invention, in the 17th and 18th centuries the art of knitting was gradually taken over by guild organized cottage industry. Interestingly, the basic technology of the modern day knitting machines is similar to Lee's machine. Even the full-fashioned machine invented in 1864 by William Cotton of Leicestershire, England used the same bearded-spring needle, which was part of the original model of Lee [17].

In the 19th century power was applied to the knitting machines and simultaneously circular knitting machines appeared on the scene. Women's stocking when knitted on original machines were a straight knitted tube, because stitches could not be added or dropped on circular knitting machine. So these products were known as hosiery. The word hosiery is derived from the old English hose, which means a covering for the leg. Now seamless stockings are knitted even on circular machines, developed in the mid-19th century. To start with cotton, wool, silk and later rayon yarns were used for making hosiery, but with the emergence of nylon in the 1940s women preferred nylon hose, because they could be permanently formed into the desired shape by heating. The use of nylon also improved the fit of hosiery due to stretchability of nylon fabrics.

Subsequently, in Great Britain, hosiery came to be associated with all types of machine-knit garments, now called knitwear. In United States they still call stockings, socks, panty hose, and tights as hosiery products. Between 1880 and 1910 knitwear was mainly a female fashion, later knitted pullovers, cardigans, skirts, men's underwear, sportswear and swimwear became popular.

Developments in the 20th century increased the production speeds of the machines and offered wider choice to pattern the knitted fabrics. Now computer controlled knitting machines have come on the scene, which are highly versatile. Knitted garments have now become every day dress.

2.3. Comparison of Knitting with Weaving

The major difference between knitted and woven structures lies in the way the yarns are interconnected geometrically an explained below:

a) In weaving, (Figure 2.1) two sets of parallel yarns are interconnected by interlacing them at right angles. Different woven structures are produced by varying this basic principle. Weaving is the oldest and the most common method of producing textile fabrics. A woven fabric is a stable construction and has a closed surface. The elastic behavior of woven structures depends predominantly on the elastic properties of the yarns used to manufacture them[7].

b) In knitting, (Figure 2.2) the yarns are initially formed into loops, and then these loops are interconnected in order to produce a textile structure. The term interlooping is used to describe this technique of forming fabrics. Based on this principle, a textile fabric is produced by using only one set of yarns. Thereby, a horizontal set of yarns (weft) could be interlooped to produce a weft knitted fabric, and a vertical set of yarns (warp) could be used to produce a warp knitted fabric[24].

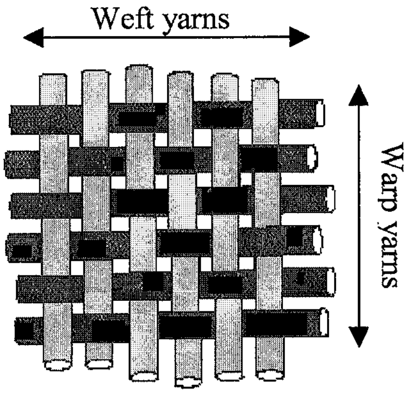


Figure 2.1 Weaving fabric

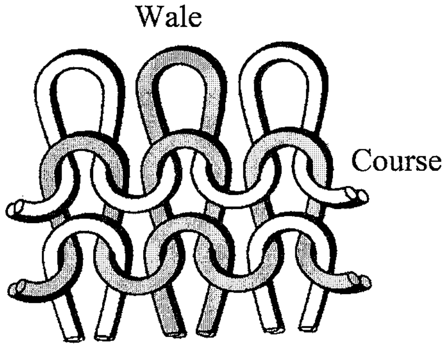


Figure 2.2 Knitting fabric

As a result of this interlooping of yarns, the surface of a weft or a warp knitted fabric is more open when compared to the surface of a woven fabric. Due to this interlooping of yarns a knitted fabric could be stretched more than a woven fabric, even when a small force alone is applied. Once this force is eased the fabric slowly returns to its original dimensions. In fact, weft and warp knitted fabrics have higher elongation values than woven fabrics due to their structure, and their elastic behavior generally exceed the elastic properties of the yarns used to knit the fabric [25].

Yarns have poor bending and torsional properties compared to their longitudinal elastic properties, and so once a knitted fabric is stretched and then released, it would slowly go back to its original state. The absolute elongation and the elastic behavior of the fabric are both determined by the knitted structure and the mechanical properties of the yarns used to knit the fabric.

Due to the structure and good elastic behavior of knitted fabrics, garments made of knitted fabrics (knitted garments) are comfortable to wear. The air trapped in the loops of a knitted garment insulates the human body against cold. At the same time the relatively loose and open structure helps the perspiration process of the human body, especially when the knitted fabric is made of yarns spun from natural fibres. Due to the interlooping of yarns, the knitted fabrics also have better crease recovering properties compared to fabrics woven from similar yarns.

The term binding can be used to describe the connection of one or more yarns in a textile fabric. The structure of a knitted fabric can be evaluated by studying how the yarns in weft and warp knitted fabrics are bound or interconnected. The actual interlooping of yarns in order to produce knitted structures depends on the knitting principle that was adopted to produce the structure, i.e. weft or warp knitting, and on the patterning elements.

Machine knitting is an important method of fabric manufacture now that, in addition to its rapid rate of production, the limited range of fabrics and end uses has been widened to such an extent that knitted fabrics compete with fabrics traditionally made by weaving.

2.4. Weft and Warp Knitting

There are two main industrial categories of machine knitting; weft knitting and warp knitting. Fabrics in both these categories consist essentially of a series of interlinked loops of yarn. Thereby, a horizontal set of yarns (weft) could be interlooped to produce a weft knitted fabric, and a vertical set of yarns (warp) could be used to produce a warp knitted fabric (Figures 2.3 and 2.4)[2]. Show on the face stitches of weft and warp knitted structures[17].

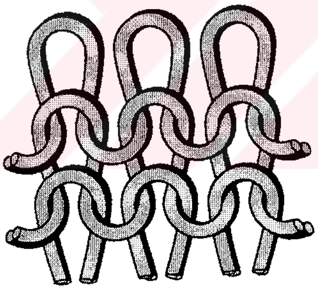


Figure 2.3 Weft knitting

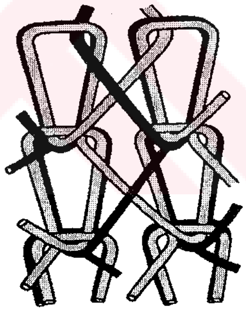


Figure 2.4 Warp knitting

The difference between weft and warp knitting methods are given by following comparison;

a) Even when the needles are fixed or act collectively in a weft knitting machine, yarn feeding and loop formation will occur at each needle in succession across the needle bed during the same knitting cycle.

b) In a warp knitting machine there will be a simultaneous yarn-feeding and loop-forming action occurring at every needle in the needle bar during the same knitting cycle.

c) A major part of the weft knitting industry is directly involved in the assembly of garments using operations such as overlocking, cup-seaming and linking which have been specifically developed to produce seams with compatible properties to those of weft knitted structures.

d) Warp knitted fabric is knitted at a constant continuous width although it is possible to knit a large number of narrow width fabrics within a needle bed width usually separating them after finishing.

e) Individual element movement (particularly of latch needles) enables weft knitting machines to produce designs and structures based upon needle selection for loop intermeshing and transfer and this also facilitates the production of garment parts shaped on the knitting machine.

f) Most patterning on warp knitting machines is based on selective control over guide bar lapping movements (i.e. the direction and extent of the overlap and underlap movements) and on the threading of the individual guides of each guide bar (i.e. with or without warp threads or with different types or colours of yarn).

g) In weft knitting, the term ‘course length’ refers to the measurement of a straight length of yarn knitted by all or a fraction of the needles in the production of a particular course.

In warp knitting, run-in per rack is equivalent to course length in weft knitting, and is measured in inches or millimeters.

2.4.1. Weft knitting

In weft knitting, these loops are formed in succession one loop at a time when the yarn travels across the fabric as it is being formed. The constituent loop of weft knitting is of the general shape shown in Figure 2.5. It is said to have length (L) i.e the length of the thread forming it from a to b. This is its most important dimension and in fact decides the area the loop covers and its width and height within a construction[19].

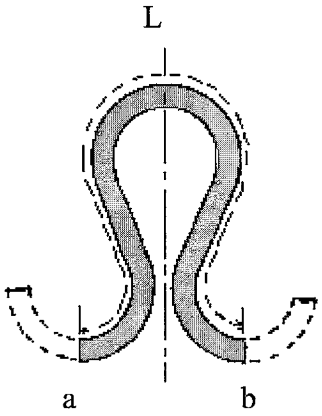
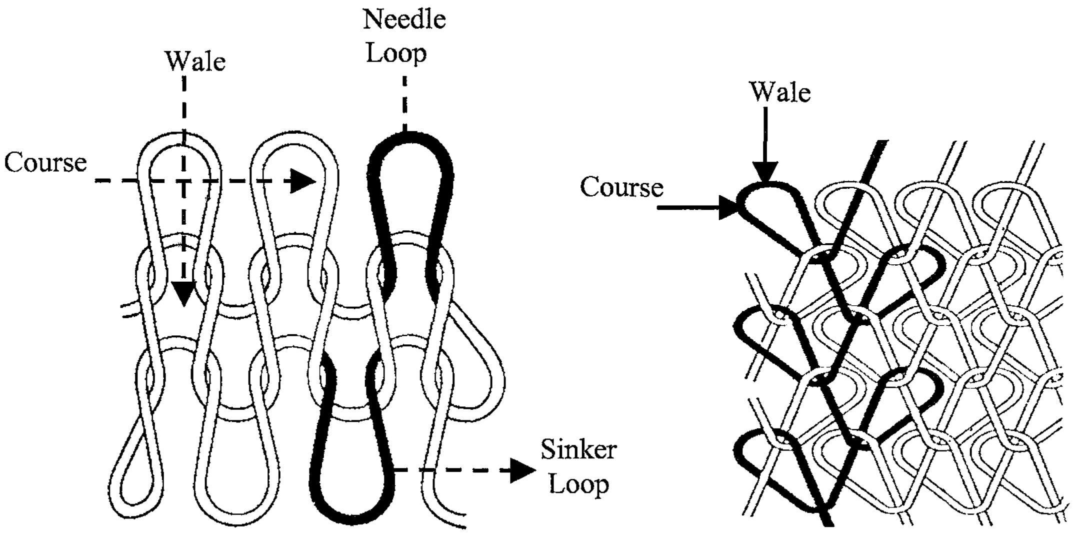


Figure 2.5 General shape of constituent loop of weft knitting

Each new row of loops is drawn through the previous row of loops in the fabric. All the loops in one row are produced from one yarn, unless special colour effects are required. It is evident that weft knitting is liable to ladder if a loop is broken, and may be unravelled course by course[21].

Loops can be related to one another and can be intermeshed with one another to form fabrics. In a horizontal direction, the relationship is a simple one of series of loops formed by the same thread diagram. In the vertical direction, loops can be joined together by intermeshing, individual loops are connected by drawing subsequent loops through previously formed loops. The result is a fabric of matrix like construction, having vertical and horizontal series of loops. Course, a horizontal row of loops is known as a course, and a vertical row of loops is known as a wale (Figure 2.6)[26].



a) Weft knit b) Warp knit

Figure 2.6 Course and wale

Both warp and weft knits are made by machine. Knitting machines may be either flat or circular. The flat-type knitting machine has needles arranged in one or two straight lines and held on a flat needle bed. The cloth is made by forming stitches on these needles. The resulting fabric is flat. Machines with flatbeds are used to make both warp and weft knits[17]. This description applies to both weft and warp knitting.

2.4.2. Warp knitting

Warp knitting is produced from a set of warp yarns, normally using at least one yarn per wale, knitted parallel to each other down the length of the fabric. These yarns are fed downwards to the knitting zone and all the loops in one course are knitted simultaneously. If each yarn were continuously knitted in the same wale, a series of unconnected chains of loops would be produced. To make a fabric it is, therefore, necessary for the chains of loops in the wale direction to be interconnected. This is done by moving the threads sideways at intervals to be knitted on adjacent wales. Warp knitted fabrics do not ladder and cannot be unravelled course by course[19].

The major interest in apparel are the four classes of warp knits: tricot, raschel, simplex, and milanese. Warp knitting machines are capable of very high speed of production because a complete course is formed by simultaneous needle movement across the full width of the fabric[27].

1) Tricot knits: Plain tricot structures knitted with two full set guide bars are by far the most popular of all warp knitted structures and are mainly based on a two course repeat cycle with a change of direction lap at each course. Tricot fabric is knit flat. On the face side the wales create the appearance of a fine, lengthwise line. The characteristics or tricot knits is the high crosswise stretch. Tricot knits are less prone to snagging, running and are very easy care. Tricot knits initially were used in our lingerie. Even in very fine denier, this fabric is stable. A tricot knit velour is the common fabric of car upholstery. The tricot knit construction has good abrasion resistance, high burst and tear strength, does not ravel, and has good stability, elasticity and resiliency[20].

2) Raschel knits: Raschel knits are lacey and mesh-like warp knits. Initially, it began as mesh knit sport shirts for men. The breath ability of this knit has made it popular for men and women's sportswear. Additional samples include a lacey knit, and power net of spandex used in foundation garments. When working with one needle bed only, raschel warp knitting machines are commonly employed for producing all-over and banded laces, curtain nets, elasticated nets for corsetry, outerwear fabrics, hairnets, veilings, nets and meshes of various types[26].

3) Simplex knits: The two needle bars used on simplex machines are mounted back-to-back so that the angle formed between the needles is about 45^o. The two sides of the fabric are identical in appearance and exhibit perfectly straight wales but a faint horizontal line occurs at each half repeat where the guide bars change direction, this being the results of the difference in loop construction at these points. Simplex fabrics are made of fine yarn but are, nevertheless, relatively dense and thick. The fabrics, which are heavier than tricot, find greatest uses in gloves, slip covers, and handbags[28].

4) Milanese knits: A milanese fabric is the equivalent of a two-bar fabric made on a bearded needle machine in that it is effectively constructed from two sets of warp threads, but the lapping movements for milanese fabrics are arranged so that each warp thread traverses across the full width of the fabric from one selvedge to the other, and not over a limited number of needles as on other types of machine. Milanese knits are characterized as a lightweight, fine fabric usually made from filament yarns. It is stable, has excellent drapability, and more costly than regular tricot. Milanesse is used primarily for better types of lingerie and dress wear[20].

In this study, experimental studies are taken place on weft knitting fabrics, so that reason warp knitting technology superficially mentioned at all.

2.5. Knitted Structures and Their Properties

2.5.1. Basic weft knitted structures

Each stitch, knitted loop and yarn loop consist of a top arc (head), two legs stitch is bound at the and two bottom half-arcs(feet). A upper and lower ends, i.e. at the head and at the feet. The first loops (yarn loops) are bound only at the head with loosely hanging feet (Figures 2.7). The knitted loops are bound only at the feet to the heads of the previous stitches[25].

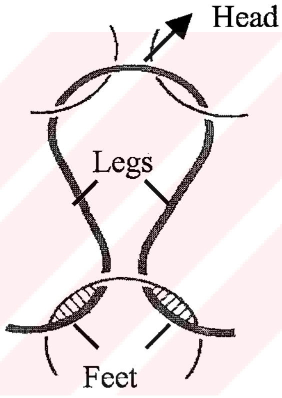


Figure 2.7 Loop structure

At the place where the legs transform into feet there are two points of contact with the previous stitch. These are defined as the binding points. Thus a stitch has four binding points, i.e. two binding points at the head and two binding points at the feet of each stitch. Two binding points, therefore, build a binding unit. Thus a stitch has a total of eight contact points, four binding points and two binding units.

A knitted fabric is technically upright when its course run horizontally and its wales run vertically with the heads of the knitted loops oriented towards the top and the first course at the bottom of the fabric.

For a stitch, depending on the position of the legs at the binding points, a technical back and a technical front side is defined. If the feet of the stitches lie above the binding points, and accordingly the legs below, then this is the technical back of the stitch, and it is called the back stitch, purl stitch, garter stitch or reverse stitch.

2.5.2. The four primary base weft knitted structures

Four primary structures-plain, rib, interlock and purl are the base structures from which all weft knitted fabrics and garments are derived. Each is composed of a different combination of face and reverse meshed stitches, knitted on a particular arrangement of needle beds.

If on the other hand, the bottom half-arcs are below and the legs above, then this is the technical front of the stitch as shown in Figures 2.8. This is called the face stitch or plain stitch, stocking stitch, jersey stitch (USA) and flat stitch (USA). A face stitch is produced by intermeshing a yarn loop towards the technical face side of a fabric as shown in Figure 2.9[25].

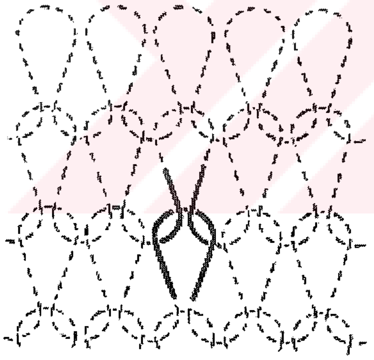


Figure 2.8 Technical front of a stitch

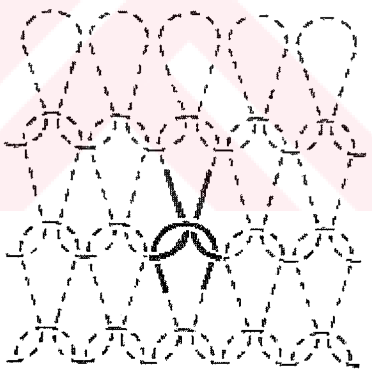


Figure 2.9 Technical back of a stitch

Depending on the geometrical arrangement of the face and reverse stitches in a knitted fabric, i.e. heads, legs and feet of stitches, the following four basic knitted structures are defined:

a) plain knitted fabrics,
b) rib knitted fabrics,
c) purl (links-links) knitted fabrics,
d) interlock knitted fabrics.

2.5.2.1. Plain knitted fabrics

The jersey or plain fabric is the most common type of fabric used in knitted wear. If a weft or warp knitted fabric has one side consisting only of face stitches (Figure 2.10), and the opposite side consisting of back stitches (Figure 2.11), then it is defined as a plain knitted fabric. It is also very frequently referred to as a single jersey fabric (single fabric)[29].

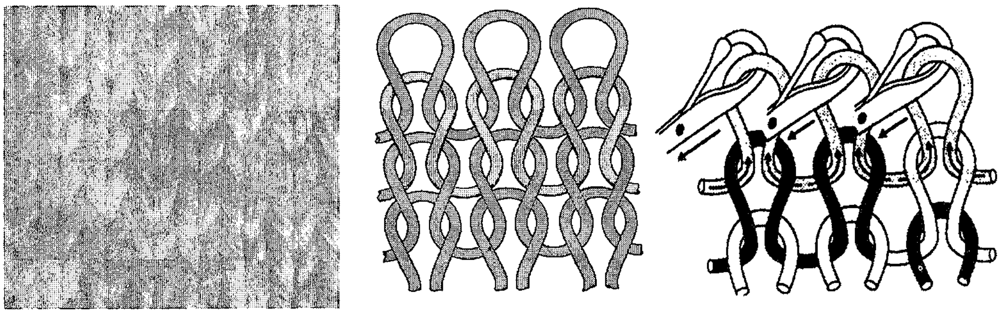


Figure 2.10 The technical face of plain weft knitted fabric

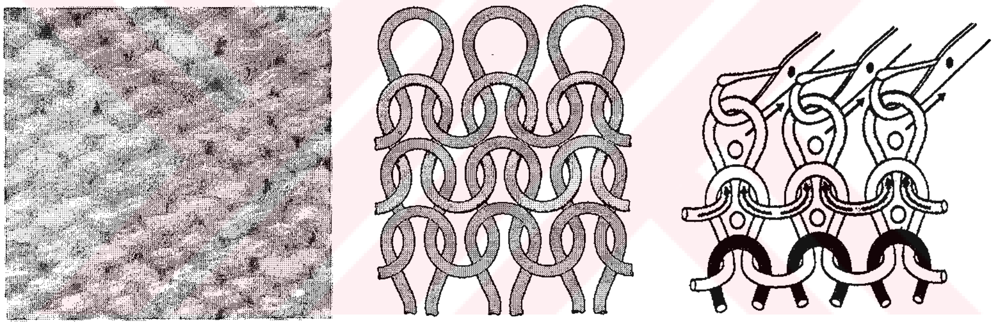


Figure 2.11 The technical back of plain weft knitted fabric

Plain knitted fabrics are produced by using one set of needles. As such all the stitches are meshed in one direction. These fabrics tend to roll at their edges. They roll from their technical back towards the technical front at the top and lower edges. They also roll from their technical front towards the technical back at their selvedges. The structure is extensible in both lateral and longitudinal directions, but the lateral extension is twice that of the longitudinal extension. The yarn loop pulled in the longitudinal direction would extend by half its length, while when pulled in the lateral direction it could extend by the entire length. The degree of recovery from stretch depends on the fibres and the construction of the yarn[30].

The fabric is produced at a high rate on only one set of needles on either circular or flat-bed machines. It is used for sweaters, t-shirts, underwear, and piece goods. Fully fashioned garments are commonly made in this structure[19].

Plain knit fabrics can be made into designs of two or more colors by use of a patterning mechanism that controls the selection and feeding of yarns and types of stitches to create jacquard knits. Jersey machines can also produce terry, velour, fleece, and sliver knit fabrics[26].

2.5.2.2. Rib knitted fabrics

If on both sides of a relaxed weft or warp knitted fabric only face stitches, i.e. the legs, are visible, then it is referred to as a rib knitted fabric and has been produced by meshing the stitches in neighbouring wales in opposite directions (Figure 2.12). This is achieved by knitting with two needle systems which are placed opposite to each other. As such these fabrics are also known as double jersey or double face fabrics. When the fabric is stretched widthwise, both sides of the fabric show alternately face and reverse stitches in each course. Once the fabric is released, it shrinks in its width, thus hiding the reverse stitches between the face stitches. These fabrics do not curl at their edges[25].

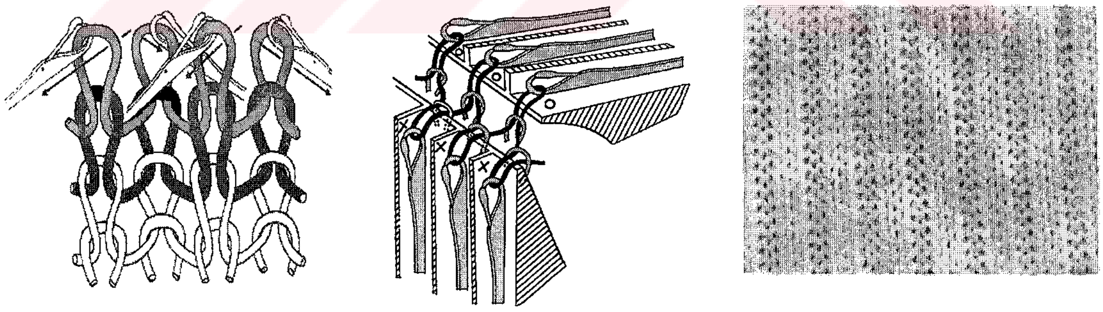


Figure 2.12 The simplest rib structure is 2x2 rib

The longitudinal extensibility of the rib structure equals that of a plain knitted structure. The geometry of the yarn path influences the elastic behavior of the knitted structures. The change of direction of the interlooping of the stitches of neighbouring wales (cross-over points) results in the wales of a rib knitted structure closing up. This gives rib structures better elastic properties widthwise than other basic knitted structures. With rib structures in the lateral direction, extensions up to 140% can be achieved. Other construction of rib structures include 2x2 rib, where two wales of face stitches alternate with two wales of reverse stitches. As the number of wales in each rib increases, the elasticity decreases as the number of changeovers from reverse to front reduces[27].

A greater quantity of yarn is required in a rib fabric than in a plain fabric similar general construction and width. Thus, rib fabrics are heavier and slightly more expensive. Rib fabrics may be produced on either circular or flat machines having two sets of needles working at right angles to each other. They are used for cuffs, collors, and trimmings, as well as piece goods and garments[19].

2.5.2.3. Purl knitted fabrics

If on the both sides of a relaxed weft knitted fabric only reverse stitches are visible, then this is defined as a purl knitted fabric. This is known as 1x1 purl (Figure 2.13). Generally, weft knitting machines are used to produce these fabrics. Purl fabrics are produced by meshing the stitches in neighbouring courses in opposite directions by using special latch needles with two needle hooks. When the fabric is stretched lengthwise, then the face stitches are visible. The fabric shrinks more in the direction of wales, and once it is released, it relaxes to hide the face stitches between the courses.

The interlooping of the stitches of neighbouring courses in opposite directions results in the courses of a purl knitted structure closing up. The structure, therefore, has a large longitudinal extensibility which is largely elastic.

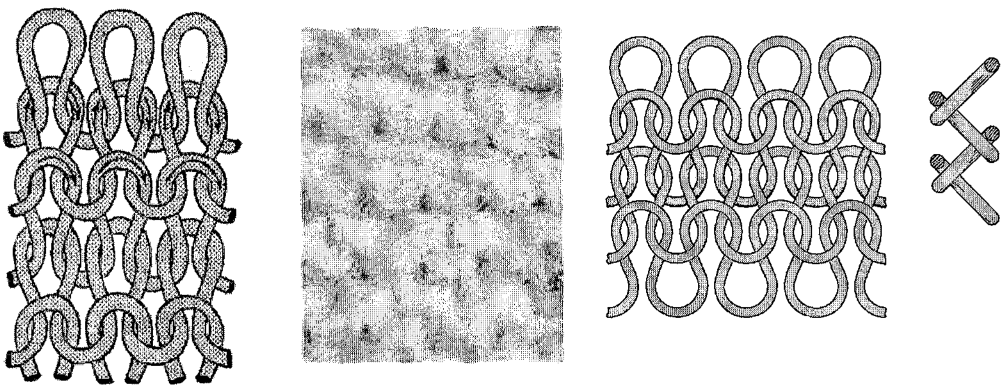


Figure 2.13 Purl knitted structure

The fabric extends easily lengthwise and for this reason is commonly used for children's wear. The rate of production is relatively slow on the double-ended latch needles that are used in flat or circular machines. There is good scope for patterning, and sometimes the purl structure is used as a means of introducing pattern into plain knitting.

2.5.2.4. Interlock knitted fabrics

These could be considered as a combination of two rib knitted structures. The reverse stitches of one rib knitted structure is covered by the face stitches of the second rib knitted structure (Figure 2.14). On both sides of the fabric, therefore, only face stitches are visible, and it is difficult to detect the reverse stitches even when the fabric is stretched widthwise.

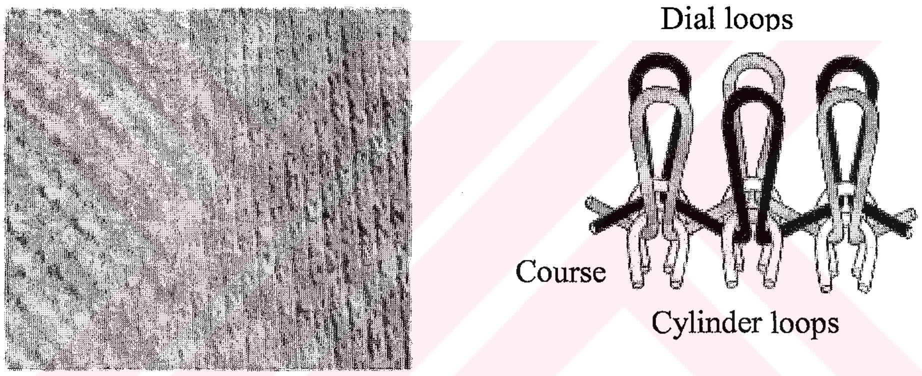


Figure 2.14 Interlock fabric structure

The geometry of the yarn path influences the elastic behavior of the knitted fabrics. The change of direction of the meshing of the stitches in neighbouring wales results in the wales of a rib knitted fabric closing up giving it better elastic properties widthwise over other basic knitted structures. The meshing of the stitches in neighbouring courses in opposite directions results in the courses of a purl knitted fabric closing up. Thus they could be stretched lengthwise more than the other knitted structures. The combination of two rib knitted structures in the interlock structure gives very little or no room at all for the wales or courses to close up, and therefore the interlock fabrics show very poor elastic properties in both directions[25]. Interlock is produced mainly on special cylinder and dial circular machines and on some double-system V-bed flat machines (Figure 2.15).

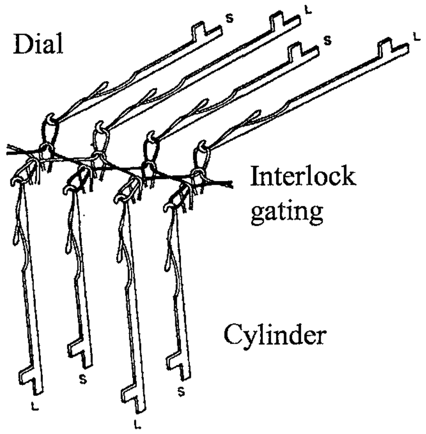


Figure 2.15 Knitting interlock

The interchange of rib prevents the fabric from contracting and gives a smooth compact appearance each side. This structure is used for cotton underwear and for double jersey outwear in wool and other types of yarn.

2.6. End Uses of Knitted Fabrics

The scope of knitted fabrics is extensive, permitting the use of the natural fibres, textured or untextured nylon and polyester yarns, as well as yarns made from acetate, triacetate and acrylic fibres. The use of stretch and elastane yarns provides additional stretch and recovery to the fabric.

Although knitted fabrics, and most particularly warp-knitted fabrics, have replaced a substantial part of the market for woven fabrics in recent years, the two classes of textile differ essentially in certain basic characteristics and each has an area of use for which the other is unsuitable.

It is possible to attain a much greater degree of firmness and stability by warp knitting than by weft knitting, and it is partly for this reason that in certain fields warp-knitted fabrics have been able to compete successfully with woven fabrics, but the dominant reason for this success is the high rate of production of the knitting processes. In addition, because of their inherent crease shedding characteristic they make up into highly successful ‘wash and wear’ garments.

In weft knitted fabric the problem of dimensional stability is more marked, and it should be noted that the dimensions of the fabric are sensitive not only to mechanical stresses but also to the effects of washing. It is one of the aims of the finisher to ensure that on washing the fabric will change its dimensions as little as possible. Excessive tension in finishing will stretch the fabric in length and cause a contraction in width and these changes will be reversed when a garment made from the fabric is washed, care in finishing and the choice of suitable finishing processes will minimize this behavior, but it is necessary for the garment manufacturer to learn from the fabric supplier and from his own tests what standard of stability he can expect in a particular fabric. It is also essential that the fabric should be handled carefully throughout garment manufacturing processes to ensure that it is not stretched or distorted since this would render a garment liable to shrinkage and loss of shape in use and in cleaning[23].

In contrast to weft knitting, which requires various sizes of machines in order to produce a range of fabric widths, warp knitting permits the production of various widths of fabric within the working width of the one machine. This flexibility of choice is useful in meeting customer needs, both in clothing manufacture and household textiles. Sheets and net curtains are examples of products requiring a range of fabric widths[18].

2.7. Types of Knitted Loops

2.7.1. Structural elements

In addition to the basic stitches tuck loops and floats are widely used in weft and warp knitting. In weft flat knitting selvedge stitches are given below[25].

2.7.1.1. The held loop

This consist of a loop that is ‘held’ by needle and but knitted for one or more courses, whilst the threads fed to these courses float across the back. A held loop (Figure 2.16 and Figure 2.17) is an old loop which the needle has retained and not released and knocked over at the next yarn feed. A held loop can only be retained by a needle for a limited number of knitting cycles before it is cast off and a new loop drawn through, otherwise the tension on the yarn in the loop becomes excessive even though there is a tendency to rob extra yarn from adjacent loops in the same course. The limbs of the held loop are often elongated as they extend from its base intermeshing in one course to where its head is finally intermeshed a number of courses higher in the structure, alongside it in adjacent wales there may be normally knitted loops at each course[19].

A held loop may be incorporated into a held stitch without the production of tuck or miss stitches in either single or double faced structures.

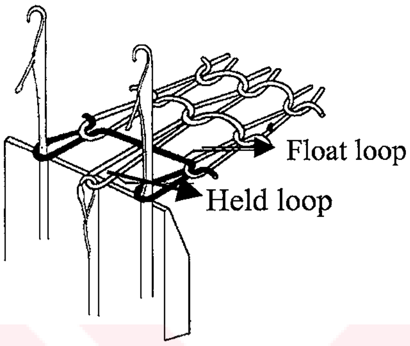


Figure 2.16 Held loop and float loop

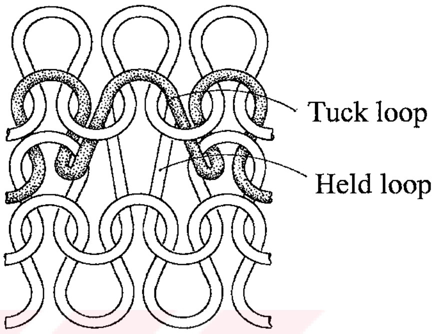


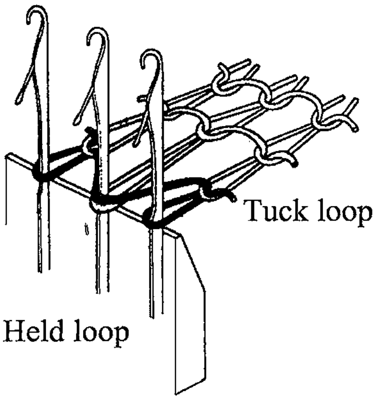
Figure 2.17 Held loop in tuck stitch

2.7.1.2. The drop or press off stitch

A drop stitch fault will result if a needle releases its old loop without receiving a new one, sometimes this technique is used to achieve a press off on all needles in a set between garment length sequences. A drop stitch or press off stitch is used very occasionally in flat knitting to cause certain loops in a plain structure to be much larger than the rest. Knitting takes place on only one bed of needles and selected needles in the other bed pick up loops which are immediately pressed off by not receiving a new yarn. The yarn from the pressed off loops flows into the adjacent loops in the other bed making them larger, giving the impression of a much courser gauge. Drop stitch wales are sometimes used to provide a guide for the cutting operation. A secure structure is only produced when a needle retains its old loop if it does not receive a new loop[17].

2.7.1.3. Tuck loops

A tuck stitch is composed of a held loop, one or more tuck loops, and knitted loops, (Figure 2.18). It is produced when a needle holding its loop (T) also receives the new loop which becomes a tuck loop because it is not intermeshed through the old loop, but is tucked in behind it on the reverse side of the stitch (Figure 2.19)[26].



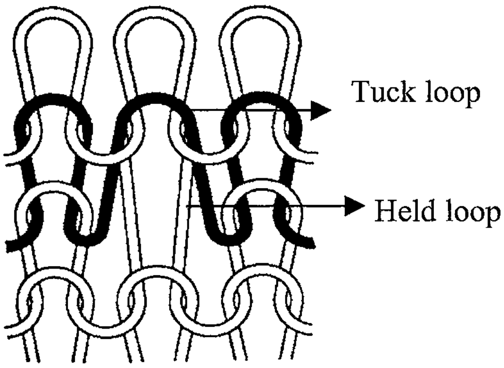


Figure 2.18 Technical back tuck loop

Figure 2.19 Technical face tuck loop

A tuck loop is characterized with an upper binding unit and with a missing lower binding unit, it is bound only at the head. Its legs are, therefore, not restricted at their feet by the head of a stitch so that the legs can open out towards the two neighbouring wales. When tucking occurs across two or more neighbouring wales, the head of the tuck loop will float across the wales. Tuck loops reduce fabric length and longitudinal elasticity because the higher yarn tension on the tuck and held loop causes them to rob yarn from the neighbouring stitches. The fabric width and lateral elasticity are increased[25].

Common construction include 1x1 cross tuck in plain fabric with its variations, and half and full cardigan in 1x1 rib fabric. Tucking can also be a colour pattern method, particularly in plain fabric fully fashioned outwear. The colour patterning is based on the premise that tuck loops side by side in a course generate a float which is not seen on the face side of the fabric[21].

Tuck loops are employed in weft and warp knitting for patterning and to influence its elastic behavior and to vary the area density and the size of the fabric. In warp knitting, the equivalent of the tuck loop is the fall plate. Generally, the tuck loop in warp knitted fabrics has the appearance of diagonally running yarns in which the loops hang in the feet of the stitches[17].

2.7.1.4. The float stitch

A float stitch is composed of a held loop, one or more float loops. It is produced when a needle holding its old loop fails to receive the new yarn which passes, as a float loop to the back of the needle and to the reverse side of the resultant stitch, joining together the two nearest needle loops knitted from it. The float or welt stitch (Figure 2.20) shows the missed yarn floating freely on the reverse side of the held loop which is the technical back of single jersey structures, but is the inside of rib an interlock structures[17].

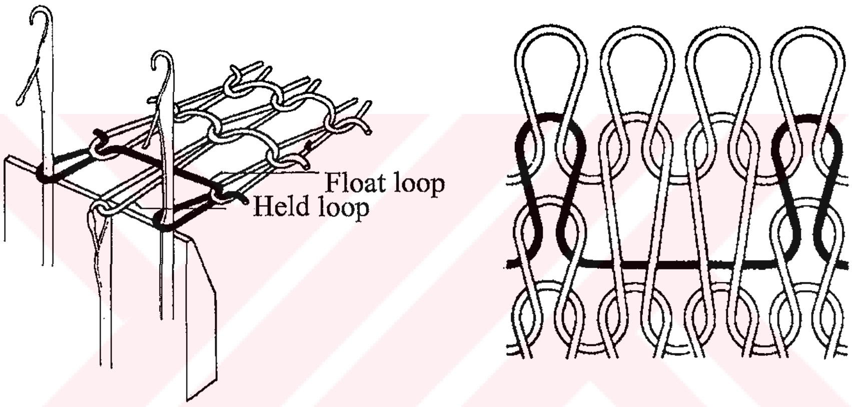


Figure 2.20 The float stitch

A float is a piece of yarn limited by stitches which, in weft knitting, floats over wales. A float is generated when a stitch is missed out of a knitted structure, and does not pass through the stitch below nor connect with the subsequent stitch. The length of yarn that would have formed the stitch lies as a float across the wales. The extensibility of the fabric is reduced. Floats are created during jacquard knitting.

A single float stitch has the appearance of a “U” shape on the reverse of the stitch. Structures incorporating float stitches tend to exhibit faint horizontal lines, they are narrower because the wales are drawn closer together and the held loop robs yarn from adjacent loops thus reducing widthwise elasticity and improving fabric stability.

2.7.1.5. Stitch transfer

A loop that is displaced after being formed so that it combines with an adjacent loop, or so that it appears in a different wale, is said to have been transferred. Transferring is used to generate holes in fabric to form lace like effects Figure 2.21. Transferring can be used to produce structural effects by inclining wales of both plain and rib fabrics[21].

The simplest example of stitch transfer is when a single loop is transferred to the next wale. The stitch is also used in the narrowing of full fashioned garments[19].

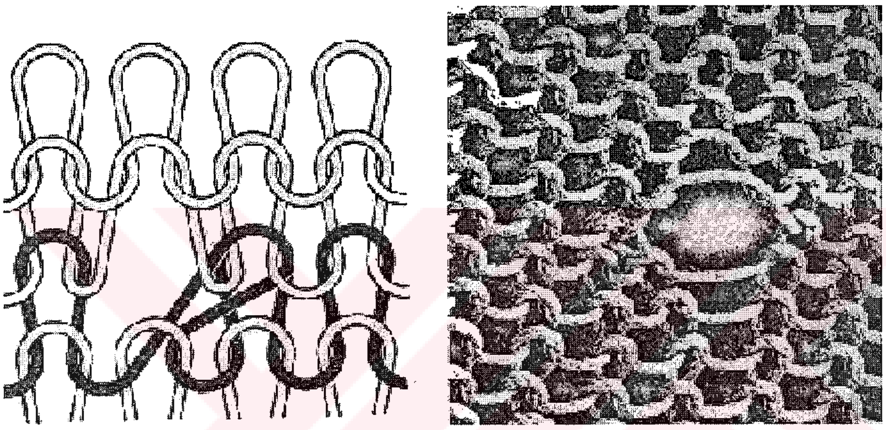


Figure 2.21 Transfer loops

Most structural and colour design in weft knitted fabric fall into the above three categories of modification. These influence the nature of the garments subsequently produced from them, largely because they modify the physical properties of the basic fabrics. They also give a wealth of visual interest to the fabrics.

2.7.1.6. Selvedge stitches

The selvedge of a weft knitted fabric is made by selvedge stitches. In these the yarn coming out of the last stitch of a course goes back through the same stitch and proceeds to the next course. Thus the stitches at the end of a weft knitted fabric have three legs, and are called the selvedge stitches. A selvedge stitch has nine contact points[25].

2.7.2. Knitting needles

In machine knitting needles are used to form stitches. Thus the primary function of knitting needles is for interlooping yarns. They perform different functions depending on the knitting technique and the needle type. Linking of new yarn loops with knitted loops and to carry the knitted loops during the early stage of the stitch formation cycle are two important functions of a needle. This central function of the knitting needle is independent of the knitting process and machine type, whether its a hand knitting machine or a high production warp knitting machine. Needles can also be considered as the primary knitting elements as they are directly in contact with the yarn during the entire stitch formation cycle. Design and development of a new knitting machine begins with the selection of the knitting needle. Once it has been decided on the type and the geometry of the needle, then the foundation for designing the knitting machine is laid. In order to select the most suitable needle for a new machine design it is necessary to establish all the possibilities for forming stitches with different types of needles and to confirm the findings[25].

2.7.2.1. Formation of the stitch in the knitting process

Needles are used in machine knitting. In weft knitting, latch and bearded needles are used, whereas in warp knitting, compound needles' are also used. One needle is required for each loop or wale. The term 'gauge' is used to indicate the closeness of spacing of the needles.

2.7.2.2. Bearded needles

Bearded needle or spring needle was invented by Rev. William Lee, in 1589. Therefore it is the first knitting needle to be invented. It is also the simplest and, therefore, the cheapest needle. Bearded needles are made from steel wire (wire bearded needle or round stem bearded needle) or from punched steel plate (flat stock bearded needle). A bearded needle is shown below (Figure 2.22).

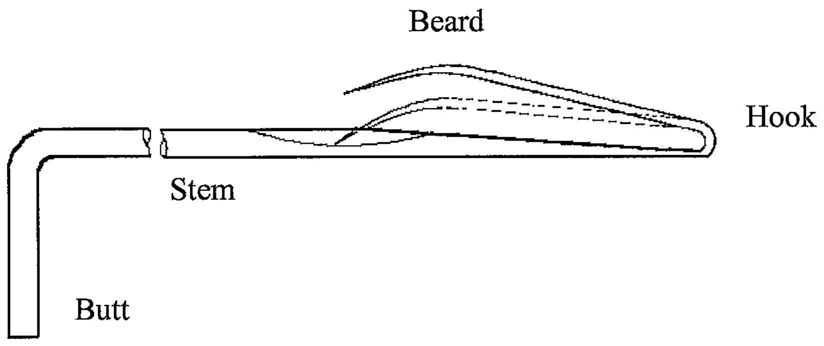


Figure 2.22 Bearded needle

By applying an external force on to the needle beard the needle hook is closed, and this is known as beard pressing. In bearded needle knitting machines this is achieved by mounting all the needles on to a needle bar and then by either moving a second metal bar, called the presser bar towards the needle beards or rotating the needle bar towards a stationary presser bar. Such an arrangement limits the ability of pressing the beards of individually, and the patterning potential of bearded needles is thus limited. This arrangement allows the needles to be reciprocated collectively. Knitting machines employing bearded needles are unable to compete in knitting the basic structures and their simple derivatives to other knitting techniques employing latch and compound needles, and their applications are reducing[23].

2.7.2.3. Latch needles

Latch needle was invented by Matthew Townsend's in 1849 and since then it has challenged the application of bearded needles in machine knitting (Figure 2.24). The latch needle is more expensive to manufacture than the bearded needle and is more prone to make needle marks in knitting, but it has the advantage of being self acting or loop controlled.

The action of the needle is the same in both warp and weft knitting, the distinction between the two methods being in the way the yarn is presented to the needle. As the needle descends, the old loop closes the needle latch, and when the needle arrives below the metal plate the old loop is knocked over. The knitting cycle is completed by the needle rising, and in so doing the newly formed loop opens the latch. The guide is moved sideways to lay the same thread in the next or some other needle in readiness for knitting the subsequent course[19].

For this reason, it is the most widely used knitting needle in weft knitting and is sometimes termed the automatic needle. Precisely manufactured latch needles are today knitting very high quality fabrics at very high speeds.

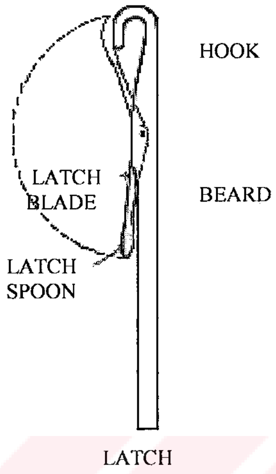


Figure 2.23 Latch needle

2.7.2.4. Compound needles

The first patent for a compound needle was awarded in 1856 to Jeacock of Leicester. The patent describes a knitting needle consisting of a needle part (the stem and the hook of the needle) and a tongue part (hook closing element). A slider can move up and down in the groove to close and open the hook. As the needle moves down, the stitches are displaced over the closed needle heads and are cast off. The method of formation of the loop is very similar, to that already described above. This type of compound needle is particularly suited to the knitting of staple fibre and textured yarns[25].

Both the two parts need to be controlled independently, and thus the new needle was named a compound needle. There are two types of compound needle in current use, the tubular pipe compound needle, where the tongue slides inside the tubular needle part, and the open stem pusher compound needle, where the tongue slides externally along a groove on the flat needle part. The pusher type is cheaper and simpler to manufacture and its two parts are capable of separate replacement. Its dimensions are narrower allowing tighter stitches to be produced[26].

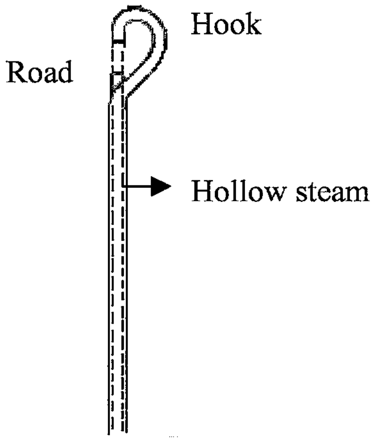


Figure 2.24 Compound needle

Today, the open stem compound needles are finding most widespread use in warp knitting. The compound needle is expensive to manufacture and each part requires separate and precise control from a drive shaft or cam system. The compound needle has a short, smooth and simple action, without latch or beard inertia problems. The slim construction and short hook makes it particularly suitable for the production of plain, fine warp knitted structures at high manufacturing speeds. Feeding yarn into a compound needle is more critical than for the bearded or latch needle because the yarn has to be laid precisely in the hook of the compound needle, in order to prevent fabric faults. By bearded or latch needle the yarn can be laid across the beard or the open latch, and it will still be taken into the needle hook. On the other hand the positively controlled two parts of the compound needle guarantees a opened hook at the time of yarn in-lay during the knitting cycle.

2.8. The Sinker

The sinker is the second primary knitting element (the needle being the first). It is a thin metal plate with an individual or a collective action operating approximately at right angles from the hook side of the needle bed, between adjacent needles. It may perform one or more of the following functions, dependent upon the machine's knitting action and consequent sinker shape and movement:

a) loop formation,

b) holding-down,

c) knocking-over.

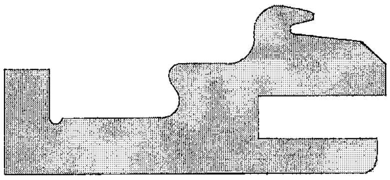


Figure 2.25 The sinker

2.9. Principles of Machine Knitting

A knitted fabric is produced by interlooping yarns of one yarn set. Yarns, which are flexible, are formed into loops and then the newly formed loops are interconnected (meshed) with knitted loops (previous loops). Generally in a weft knitted fabric all the stitches in a course are formed from the same yarn, and therefore in a weft knitted fabric the yarns are in the direction of the courses. On the other hand in a warp knitted fabric the stitches in a course are formed with different yarns. In fact each knitting needle is provided with a separate yarn (this is the minimum requirement, on commercial fabrics each needle is provided with at least two yarn ends). Therefore in warp knitted fabrics the yarns are in the direction of the wales, parallel to the fabric selvedges.

In machine knitting the interlooping of yarns is realized with various mechanical elements termed knitting elements. The knitting elements are manufactured to a very high degree of precision using high quality metals, in order to guarantee the production of quality knitted fabrics.

In machine knitting the interlooping of yarns is achieved in steps. These steps are called knitting steps. To form a new stitch all the knitting steps have to be carried out in the correct sequence. The correct sequence of the knitting steps is known as the knitting cycle.

In weft knitting a yarn is laid on to the needles individually with a yarn feeder or a yarn carrier, while in warp knitting every needle is provided with a yarn by using a knitting element called yarn guide. Thus in knitting as in weaving the yarn has to be provided to the knitting zone, and this is considered as the first knitting step. This step is known as yarn laying. Loops need to be formed form the newly provided yarn, and then they can be interconnected with knitted loops in the needles. As such another important knitting step is the loop formation, and the final step of a knitting cycle is the linking up step, in which the newly formed yarn loops are drawn through the knitted loop in the needles converting the yarn loops into knitted loops and knitted loops into new stitches. However, before the newly formed yarn loops can be pulled through the knitted loops the needle hooks, which had to be opened to accommodate the new yarn loops in them, must be closed before the yarn loops can be connected to knitted loops. This very important step in forming stitches is called bridge formation. The described steps are the most important fundamental steps of machine knitting, and they are common to all the different knitting techniques available at present, and therefore these are known as the Primary Knitting Steps. The order in which these are carried out will depend on the knitting technique and the knitting needle[25].

CHAPTER 3
FABRIC QUALITY CONTROL

3.1. Introduction

Knitted fabric usage have been increasing all over the world because of the simple and quick production technique, lower production costs, being more comfortable, softness of fabric structure, appropriate to the fashion and variety of products.

The faults which occurred during knitting, become more visible while other processes. When it become end product it would be impossible to correct these fabric faults. The basic principle for the end product which responds customer requirements and needs is to produce knitted fabric without fault. Quality function deployment is a product planning tool based on customer requirements from design phase through whole organization. Reliable, competitive, high quality knitted products and satisfied customers are aimed by using quality function deployment applicated on a knitting company[31].

It is common to perform inspections and tests at predetermined intervals on purchased raw materials and at various stages in the manufacture of products. In yarn and fabric manufacturing construction characteristics are those most often tested. The purpose is to make sure that the correct product is being properly manufactured a usual precondition for meeting the requirements of a performance specification. After dying or finishing operations, critical performance characteristics may be measured routinely as a way of verifying product quality. The finished material may also be inspected for shade match, color uniformity, and visually apparent defects. Quality inspection of sewn products focuses on dimensional tolerances, seam quality, and overall appearance[32].

Since quality control tests are often performed several times a day on production lots of a textile product, it is very important that they can be completed rapidly and economically. When the test results do not fall within the expected range, production workers must be notified so corrective measures can be taken. Furthermore, production lots that fail the tests might have to be reworked, sold as seconds, or discarded[33].

3.2. Quality Control

Textile products are tested at various stages of production to assure quality processing and products. Manufacturers may use quality control testing as a marketing tool, in that trade names imply to the consumer that certain levels of quality are assumed to be standard for products produced by the manufacturer. Quality control testing aids the manufacturer in assuring that the expected level of quality is maintained[34].

3.3. Standard Test Methods

Test methods are developed for textile products by several different organizations. They are typically developed in response to a need expressed by an individual manufacturer, a product user or occasionally by a consumer group.

Over the years many organizations dealing in textiles and textile products have written specifications for what they sell or what they want to buy. Clearly that means that different companies' specifications for the same product are often different. Some might even choose different test methods to measure the same characteristics of a material. Consequently, each time buyers set out to write contracts with various sellers, they have to make sure they are talking about the same specifications and test methods. Many buyers in particular do not have the expertise to write good specifications and they want to be able to buy the goods with some confidence that they will be serviceable. In other words, there are strong incentives for those buying and selling textiles and textile products to agree on standard specifications and standard test methods that everyone can refer to and use[32].

A specification or test method becomes "standard" because one or more groups of people agree to use it. One or more employees of a company can decide on a company standard; members of an association can agree on an association standard; companies and associations in a whole country can agree on a national standard; and by extension, a group of different countries can develop an international standard. The concept of agreed on standards is not limited to specifications and test methods but also applies to definitions, classifications, and various procedures for doing things.

Finally, once a test method is approved as a standard test method for the organization, American Association of Textile Chemists and Colorists (AATCC) and the American Society for Testing and Materials (ASTM) and the International Organization for Standardization(ISO), the method must undergo periodic reconsideration and re-approval in order to be retained as a standard test method. This extensive development and review process is intended to assure that standard test methods meet the needs of users. Test method development and revision are on going processes. New test methods are introduced every year and older methods are dropped in response to the changing needs of the textile, apparel, and home furnishings industries and their consumers[34].

Although many voluntary international groups promote technical cooperation, the major worldwide specialized organization for standardization is the ISO. Its work "brings together the interests of standards procedures and standards users in almost all areas of technology except electricity and electronics. ISO is a nongovernmental organization, but many of its national members are government agencies[32].

3.4. Properties of Fabrics

The demands made on a fabric, and hence the properties and characteristics it must have, are determined by the use to which it is put and also the requirements of satisfactory behavior in making-up. Certain requirements are common to most fabrics, adequate strength and durability for example, whilst other properties such as waterproofness or resistance to agencies such as acids or alkalis are demanded for fabrics to be used for special purposes. The uses to which fabrics are put are extremely wide and diverse and the properties and characteristics which are of importance are correspondingly diverse, as are the corresponding methods of examining and testing fabrics.

The performance characteristics of fabrics can be grouped in a number of broad categories as follows. The entries in each category are illustrative only, since they cannot be exhaustive:

Mechanical properties

1) tensile,
2) tearing and bursting strengths,
3) resistance to abrasion,
4) dimesional stability,
5) stretch and recovery.

Aestehetic acceptability

1) handle and drape,
2) crease recovery,
3) easy care properties,
4) lustre,
5) appearance retention including colour fastness,
6) colour matching.

Comfort

1) permeability to air and moisture vapour,
2) thermal insulation,
3) stiffnes,
4) smoothness.

Garment manufacture

1) sewability,
2) dimensional stability,
3) tailorability,
4) freedom from static.

Special applications

1) flame retardance,
2) waterproofness,
3) wind resistance,
4) resistance to-acid,
5) alkalis and industrial solvents.

The above classification is mainly applicable to clothing fabrics but it should be remembered that the textile industry produces a vast range or industrial fabrics from the extremely lightweight to very heavy fabrics, for uses such as conveyor belts and other engineering purposes[19].

3.5. Knitted Fabric Properties

For all knitted fabrics, whether of weft or warp knitted types, it is necessary to specify the basic requirements of width, mass per unit length or per unit area, the construction and linear density of the yarns to be used, including fibre composition, and the knitted construction. Other manufacturing particulars are the number of wales per cm and courses per cm, and these are quite commonly specified. For warp knitted fabrics the 'run-in' of the yarns, and for weft knitted fabrics the stitch lengths of the yarns, can be specified but this would be unusual[21].

In respect of finishing treatments it is necessary to stipulate color fastness, and possibly the type of dye, and any special finishes the cloth is to be given. It is usually important to stipulate the dimensional stability of the fabric, that is the maximum dimensional changes acceptable in washing, preferably by an accepted standard method.

This dimension the loop density is the most important one in defining knitted fabric properties and is directly related to appearance, weight per unit area, thickness, drape and many other factors.

The loop length is the absolute quantity of any knitted fabric and is directly related to the loop density. In general terms, for any knitted fabric, as the loop size increases the loop density decreases. For simple fabrics the relationship can be expressed in a single equation:

$$S = \frac{K}{L^2} \tag{3.1}$$

Where 'S' loop density, 'L' loop length, 'K' constant.

A large amount of data and research work has been carried out relating the above expression to the characteristics of plain fabric, and definite values of 'K' have been proposed. For other constructions, while the proposition still holds the situation is more complex and further study is required[21].

3.5.1. Stitch length

This is a parameter of great importance in weft knitted fabric geometry, since it determines the dimensions of the fabric in the relaxed state: that is, the state in which the fabric is dimensionally stable when washed.

The practical significance of this is that, it is possible to control the stitch length during knitting, and hence to knit fabric that will have the required dimensions when brought to the dimensionally stable form in finishing. Without this knowledge, satisfactory fabrics can be produced only by trial and error.

The situation is different for warp knitted fabrics. These are most commonly knitted from thermoplastic yarns, which can be heat-set. Consequently, these fabrics can be brought to the required dimensions during finishing and heat-set to retain these dimensions during washing. These finished dimensions therefore need not be the relaxed dimensions of the fabric 'as knitted'[19,33].

In this respect warp knitted fabrics may be contrasted with weft knitted fabrics, which are used more for articles for which easy extension and form fitting are valued.

3.5.2. Course length

For some structures with complex geometry an average loop length value is largely irrelevant and expressions of 'quality' are given indirectly, either as a course length or as loop density as measured on one side of the fabric.

A course length is determined by unroving yarn from a known number of loops of the fabric and measuring its length using a drimp tester. To arrive at the loop length the mean of several course lengths is divided by the number of loops in the course extracted. It is usual to use multiples or fractions of 100 loops in this measurement.

In a circular fabric the structure is composed of a number of courses that spiral around the fabric. The number is dependent on the number of knitting sections (feeders) around the machine. Each feeder can be regarded as a separate knitting entity responsible for the course length/loop length that it is producing. Each feeder can be said to produce a different course length. It is the aim of fabric quality control to make them as near as possible to the specified value. When some courses are wildly out of specification and differ from one, another, the fabric has horizontal bars that degrade its appearance and lower its perceived quality. If the mean value of the course length is out of specification, every other fabric property is also affected[21].

Most modern circular machines producing simple fabrics are fitted with positive feed units that ensure much closer tolerances between feeders in respect of course length. For machines that do not possess positive feed or for fabrics that cannot be knitted under positive feed conditions, a laborious setting up procedure is carried out with the machine set on producing a simple fabric, e.g. plain, 1x1 rib, interlock etc. The feeders are leveled using a combination of yarn speed meters and fabric analyzes. When the machine is leveled to within tolerances for loop length, the necessary adjustments are made to switch it to producing the more complex fabric[23].

3.5.3. Tightness factor

Corresponding to the cover factor defined previously for woven fabrics, there is a 'tightness factor' for knitted fabrics which indicates the relative looseness or compactness of the knitting. The factor is related to the ratio of the surface area occupied by the yarn in a loop to the area of fabric enclosed by the loop. The study of fully relaxed plain weft knit worsted structures provided the basis for the experimentally derived formula:

$$\text{Tightness factor} = \sqrt{\text{t}} \div \ell \qquad (3.2)$$

where t: yarn tex and ℓ : loop length (mm).

A fabric with a large loop length and course yarn could have the same tightness factor as a fabric with a small loop length and fine yarn.

The tightness of the fabric has an important bearing on such fabric properties as dimensional stability and ease of felting, handle and drape, bursting strength and resistance to abrasion.

Account is not taken of the effect of twist, fibre density, and the extent to which loops overlap each other in the structure, all of which would be considerations in the determination of fabric cover[19,33].

3.5.4. Weight per unit area and cover factor

Weight per unit area of fabric is an important property that is again related to a host of other properties. The 'weight' is determined by two factors that interact: the loop size and the yarn size. The effect of the loop size is simple to express: if the size of the yarn remains constant, then increase of loop size produces a decrease of weight per unit area.

Usually in knitted fabrics, for fabrics of a similar construction, as loop length increases so the size of yarn increases. Yarn sizes are themselves expressed not in terms of diameter but in weight per unit length.

In a knitted fabric, to maintain cover, as the length of loop doubles so the diameter of the thread must double. Cover is a simple ratio of the area of a knitted fabric covered by yarn to the area covered by the gaps in between loops. It can be demonstrated that for a given knitted structure, if the cover ratio is maintained through a range of fabrics with different loop lengths, then those fabrics are related in characteristics of tightness looseness and other physical properties[23].

This concept of cover leads to the property of 'normality' of a knitted fabric. A 'normal' fabric is one that is neither too tight and stodgy nor too loose and floppy. Lay observers given a range of fabrics of differing loop size and yarn size make surprisingly similar judgments on what 'normality' is in a knitted fabric intended for normal apparel.

There is a simple formula that can be used to express 'cover factor' or tightness factor, taking into account and abbreviating diameter of yarn, length of loop and loop density.

$$\text{Cover factor (cf)} = \frac{\sqrt{\text{count in tex}}}{\ell} \tag{3.3}$$

Where 'ℓ' loop length.

When discussing cotton fabrics, that it is often difficult to measure dimensions and quantities because of the extensible nature of the material and the possibility that it is under stress at the time of measurement.

Measurements of fabric taken from a roll or lapped pile must always be considered to apply to the state that the fabric is in at the time of measurement. Unfortunately knitted fabric may change dimensions with time, handling and with subsequent wet treatments including steaming, and such changes can occur after the garment has been produced and sold to the public.

The concept of the related state for knitted fabrics is well recognized and documented. Quality control must ensure that before knitted garments are cut, the fabric is in a relaxed or near relaxed condition, i.e. that there will be little shrinkage of the fabric or garment when it is in the consumer's possession. Relaxation tests can be carried out on fabric as a routine procedure, or as spot checks on suspect deliveries. There are British Standard procedures for relaxation testing (BS 1955:1981(86) and BS 4736:1985), and some of the large retail or wholesale purchasers have established tests of their own. Most test procedures involve agitation in aqueous solution followed by measurement under water, or spinning and tumble drying. They attempt to reproduce the conditions under which the garment will be laundered during usage.

3.6. Fabric Test Methods

A textile may have all the qualities and properties needed to fit it for some particular purpose, but unless it is strong enough to resist the forces it will encounter in use it is of no value. In use cloth may be liable to fail by breaking when a straight pull is applied, by ripping and tearing, and by bursting when a force is applied normal to its surface. Laboratory test methods are used to measure the resistance of cloth to each of these forces and generally tests are made on the fabric in the unused state, which may be referred to 'as received'. When fabric has been in use under a variety of conditions, including possibly cleaning processes, exposure to light and other agencies, the performance of the fabric will gradually diminish. It is therefore important for an appropriate level of strength to be set and attained so that, despite a subsequent drop in performance, the material will still give reasonable satisfaction throughout the 'life' of the garment or other textile product[33].

When an article is produced, it has to be suitable for its end uses. It must conform to a set of specifications that have been laid down for it. Quality in textile products can thus be defined as the extent to which an article conforms to its specifications.

For example, a shirt should not only be attractive and fit, but should also possess quality criteria such as shape retention after washing, resistance to colour fading, or lasting wear. A method to evaluate the textile products relative to these quality aspects is to conduct tests that simulate actual wear conditions. This is done by taking a sample of the material and testing it using various instruments. Experiments are conducted by research organizations, government standards institutions, consumer organizations, and textile buying offices to evaluate the quality of textile articles, and establish minimum performance requirements[35].

The following section will consider some of the common tests which are performed on textiles.

3.6.1. Breaking strength

There are two ASTM tests for fabric breaking strength (Figure 3.1) ; they differ in the form of the specimens prepared for testing. ASTM standard D 5034 specifies the grab test and ASTM standard D 5035, the strip test.

There are two forms of the strip test. One, the raveled strip, requires that the fabric specimen be cut 10 mm (1/2 in) wider than the final width to be tested (which can be either 25 mm or 50 mm). Then 5 mm (1/4 in) is raveled from each side. Thus, because the full width of the specimen is clamped, you can relate strength to width, or even to number of yarns. In the cut strip test, the specimens are cut the width of the jaws or narrower, so that all yarns will be gripped during the test. In this test, accuracy depends on exact alignment of the specimen in the jaws; any deviation will cause some of the yarns to not be gripped and errors will result[36].

In the grab test, the specimen is cut wider than the jaws (total width: 100 mm or 4.0 in), and gripped in the middle. The method gives the effective strength of the fabric, and not the strength of the yarns actually gripped between the clamps. It is an effective strength because the yarns adjacent to those that are gripped contribute some helping resistance to the gripped yarns, giving a higher strength than with the cut and raveled strip tests. In a modification of the grab test, the yarns on each side, that are not gripped in the clamps, are cut so that they do not contribute to the breaking strength and the testing more generally resembles that of the strip tests.

Which test to use depends on the fabrics and whether the actual or effective strength is required. When a fabric cannot be raveled, as nonwoven or heavily coated fabrics usually cannot, then the raveled strip test cannot be used. Another consideration may be the time required for preparation of test specimens. Those for the grab test are simpler to prepare[34].

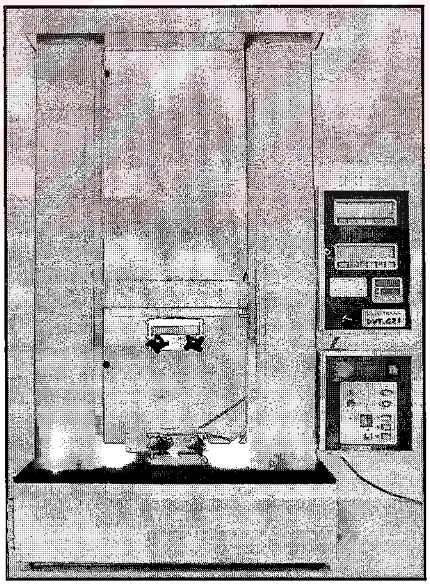


Figure 3.1 Breaking strength tester

Many of the performance tests used for woven fabrics are suitable also for knitted fabrics, although the level of results expected may be different. The strip test for the tensile strength of cloth is usually unsuitable for knitted construction since these distort to an acceptable degree when stretched. To ensure that a knitted fabric has an acceptable level of strength it is usual to specify a bursting test result[37].

3.6.2. Tensile strength

This term refers to the breaking load or force, expressed in units of weight, required to break or rupture a specimen. A number of methods can be used to test the tensile strength of a textile sample such as fibre, yarn or cloth. The sample is clamped between two sets of jaws, a force or load is applied to it until it ruptures and the average breaking load is recorded in the 'strip test', and the ‘grab test’.

For determination of the tensile strength and breaking elongation of single yarns and fabrics. Fabric specimens may also be subjected to seam slippage, wingrip and similar tests[35,36].

Some of the international testing standards are given below ;

1) one-inch grab - ASTM C 5034.
2) strip test - ASTM D 1682.
3) ISO 5081, ISO 5082.
4) JIS L 1096
5) BS 2576.

3.6.3. Bursting strength

Some fabrics, especially knitted ones, are stressed in many directions at one time. The bursting strength of a knitted fabric is the ability of the material to resist rupture by pressure. To test the bursting strength of such fabrics, a hydraulic bursting strength tester can be used. A fabric sample is clamped over a thin flexible diaphragm which expands as the pressure increases. The fabric eventually bursts, and the pressure gauge reading gives a measure of the bursting strength of the fabric[32,35].

For random nonwovens and knits, it is usually not desirable to use any of the above tests, but to employ a special adaptation on tensile testers to determine bursting strength. This is a multi directional strength test, in which the tensile force is applied in all directions, rather than in just one direction. The multi directional force can be a steel ball that is pushed up through the specimen held in a circular clamp. The force required to rupture the specimen is recorded. Alternatively, a rubber diaphragm inflated with increasing pressure can be used. The pressure under the specimen, again held in a circular clamp, is increased until the specimen ruptures[34].

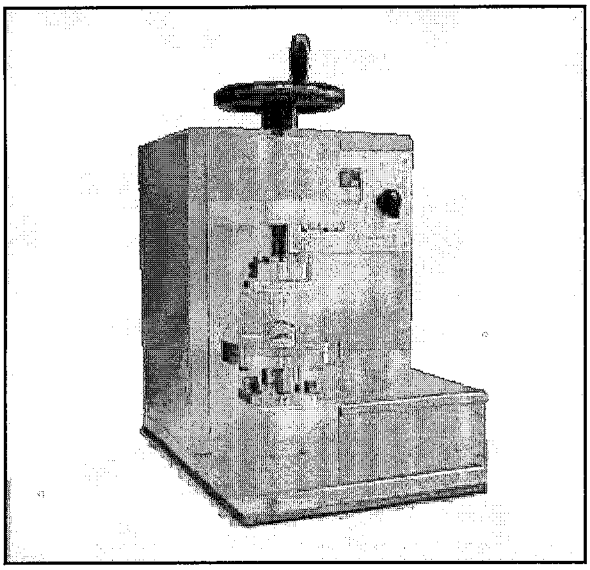


Figure 3.2 Digital bursting strength tester

Some international testing standards related with nonwoven and knits are given below;

1) ISO 2758/2759/3303/3689/2360,
2) ASTM D 3786,
3) BS 4768,
4) JIS L-1096

3.6.4. Stretch and recovery

The comfort of a garment, its closeness of fit, and appearance in use, are influenced by the extent to which the component fabrics will stretch and recover from extension. The stretch and recovery of common woven and knitted fabrics made from conventional yarns is limited, but by the inclusion or substitution of textured yarns, elastane fibres, or the application of special fabric manufacturing and finishing procedures, a range of fabrics offering different degrees of stretch and recovery is possible[19].

3.6.5. Wrinkle recovery tester

The wrinkle recovery tester (Figure 3.3) is used to determine the appearance of textile fabrics after induced wrinkling to determine a fabric's ability to recover after wrinkling under a predetermined load for a set period of time.

It is applicable to woven and knitted fabrics made from any fibre or combination of fibres, particularly those for outerwear and light wear fabrics containing wool or wool blends. Materials, which are insufficiently stable to carry a defined crease, for example, those which are limp, thick or have a tendency to curl, can be assessed for wrinkle resistance with this device. Conditioned specimens are wrinkled under specified conditions, temperature, relative humidity, load and time. Their appearance is then evaluated against three dimensional replicas or photographic standards.

A specimen is cut and wrapped, face outwards, around the upper and lower flanges of the instrument. Steel springs are used to clamp the specimen to the flanges. Wrinkling is induced by with drawing a locking pin, which allows the upper flange to fall. As it falls, it spirals around the central pillar, distorting the fabric, before coming to rest on the lower flange.

Dependent on the test method different combinations of weights are applied to the resting top flange. After the prescribed period, the specimen is carefully and gently removed. After a further recovery period, it is assessed against the appropriate reference standard[39].

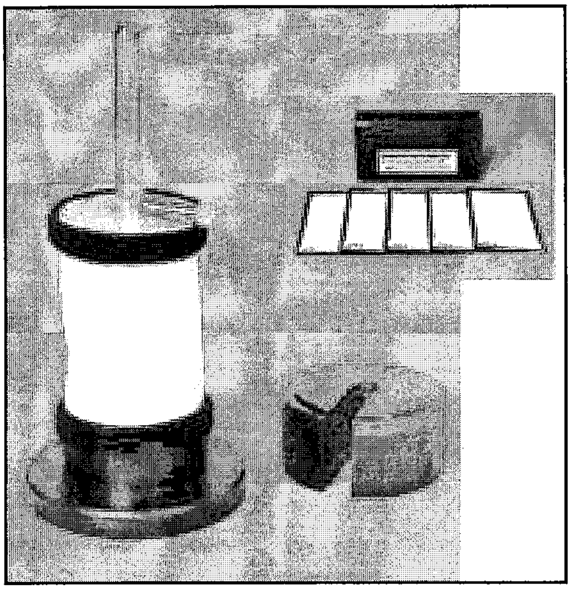


Figure 3.3 Wrinkle recovery tester

Some international testing standards are given below;

1) AATCC 128,
2) ISO 9867,
3) ENKA 3061,
4) M&S P123

3.6.6. Elongation

Elongation is the increase in length of the specimen from its starting length expressed in units of length. The distance that a material will extend under a given force is proportional to its original length, therefore elongation is usually quoted as strain or percentage extension. The elongation at the maximum force is the figure most often quoted. The elongation that a specimen undergoes is proportional to its initial length. Strain expresses the elongation as a fraction of the original length;

$$\text{Strain} = \text{elongation} / \text{initial length} \qquad (3.4)$$

This measure is the strain expressed as a percentage rather than a fraction;

$$\text{Extension} = (\text{elongation}/\text{initial length}) \times 100 \qquad (3.5)$$

Breaking extension is the extension percentage at the breaking point. When an increasing force is gradually applied to a textile material so that it extends and eventually breaks, the plot of the applied force against the amount that the specimen extends is known as a force elongation or stress strain curve[36].

3.6.7. Snagging test methods

Snagging of fibers or yarns often occurs as fabrics come in contact with rough surfaces or undergo the rubbing process associated with abrasion in actual wear. Knit fabrics are particularly prone to snagging, although both knits and wovens constructed from filament yarns can undergo snagging, regardless of the type of knit or weave. Depending on the fiber content, filament yarns usually do not break as easily as staple yarns; therefore, the problem of snagging is more evident in fabrics constructed of filament yarns. Any fabric with long yarn floats such as in a satin weave, is more likely to snag than are other types of fabric structures. Snagging can result in yarn breakage or in unsightly puckering as the yarn is caught and pulled[34].

There are two test methods for snagging. ASTM D 3939 is appropriate for most woven or knit apparel or home furnishing fabrics, but not for very lightweight, or open structured fabrics. In this test, fabric specimens on a rotating cylindrical drum are subjected to spiked balls, which bounce randomly on the fabric surface, causing the fabric to snag. In ASTM U 5362, fabric specimens are made into covers for bean bags (Figure 3.4) and are randomly tumbled in a cylindrical chamber (Figure 3.5) which has an inner surface of pins. This test method is more appropriate for lighter weight fabrics, and has been used for hosiery. In both tests, results are evaluated using a visual scale[19].

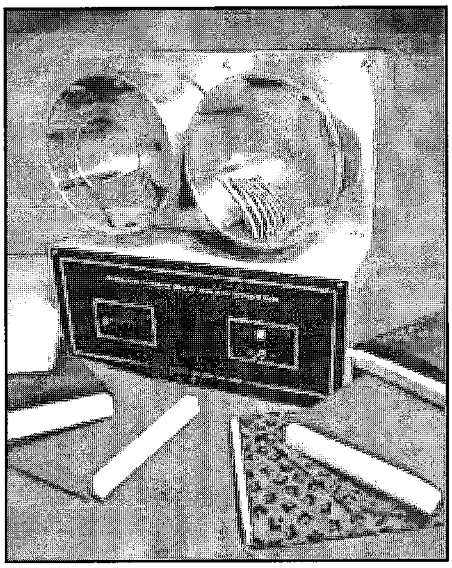


Figure 3.4 Bean bag snag tester

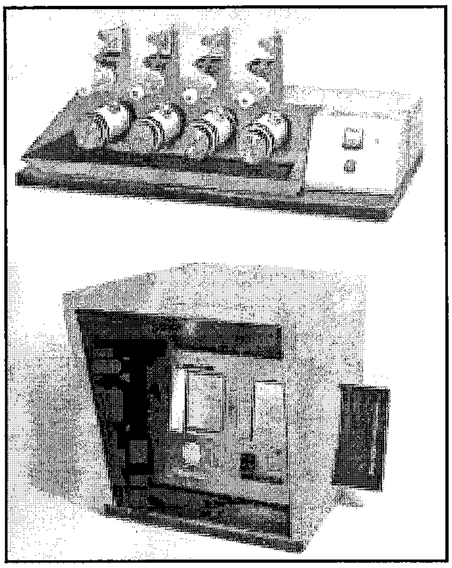


Figure 3.5 Mace snag tester

3.6.8. Pilling test method

Textile fabrics are prone to develop balls of fibre on the surface, which are known as pills. Pilling resistance is usually evaluated on a scale of 1 to 5, where 1 represents severe pilling and 5 represents no pilling.

The determination of the rating of pilling resistance is a subjective visual assessment. Due to this it requires extreme care and thorough training in the assessment technique to ensure the rating is accurate. A minimum of two trained operators should rate the tested specimens separately. Where there is uncertainty or considerable discrepancy in the raters evaluation, a third trained operator should be involved in determining the rating, and the mean of the three evaluations reported.

Where possible the appropriate set of pilling rating photographs should be used in the assessment. Where a fabric is evaluated for which photographic standards are not available, then verbal descriptions of the different levels of pilling should be used in combination with photographic standards of the fabric type which most closely resembles the fabric being tested[38].

The ICI pilling (Figure 3.7) viewing cabinet with lighting set to cast a shadow from any pills formed on the surface is an important tool to assist in the rating process. Unfortunately, this shadow effect is lost on black, navy and other very dark coloured fabric. This results in failure to detect severe pilling on these very dark coloured fabrics, if the lighted assessment box is relied on alone to make the pilling assessment.

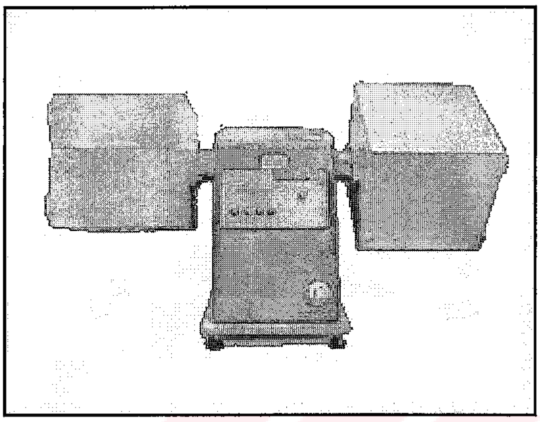


Figure 3.6 ICI pilling box

To overcome this, experience in various commercial textile testing laboratory has shown it is absolutely essential to view very dark coloured pilling samples from various angles in conjunction with the photographs and to feel for pills on the surface with the finger tips. This highlights the degree of pilling which has occurred and minimizes the possibility of a totally false rating being given to a very dark sample.

Failure to detect and prevent pilling on dark coloured fabrics results in severe customer dissatisfaction in actual use. This is due to the propensity of the pills to pick up light coloured lint and fluff during wear and washing processes, which contrast very vividly with dark coloured fabric, giving the garment a shoddy, excessively worn appearance after only a very short period of wear[19,32].

To determine abrasion resistance by the number of rubs to breakdown or by the loss in mass of the specimens. Also the test of pilling on the Martindale (Figure 3.8) are formed after a given number of rubs are counted[38].

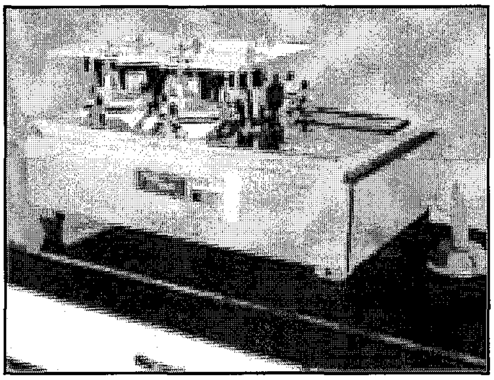


Figure 3.7 Martindale abrasion pilling tester

Standard test methods usually requested for pilling evaluations are: woven fabrics IWS 196 Martindale method, knitted fabrics BS 5811 ICI pill box.

3.6.9. Abrasion resistance

Because of the difficulty of reproducing 'in use' abrasion in the laboratory there are probably more instrumental methods and instruments for testing abrasion than for any other textile property. One reason for the difficulty in reproducing abrasion in the laboratory is that laboratory abrasion tests are usually conducted on new fabrics while, in actual use, abrasion occurs both before and after laundering or dry cleaning. In actual use, many different abradent forces also act on a fabric at one time, while most laboratory tests simulate only one type of abrasion[32].

The abrasion of a fabric is the rubbing away of its fibres and yarns. The ability of a fabric to resist abrasion can be tested in a number of ways. One way is by the 'flexing and abrasion method' which can be used for all fabrics except floor coverings. Using a flex abrasion tester (Figure 3.8), a sample of predetermined dimensions is pulled and rubbed in continuous cycles until it breaks. Its abrasion resistance is determined by the load applied by the tester, and the number of cycles taken to break the sample. Visual inspection of the abrasion is also made. The 'Martindale tester' is also well known. In this apparatus, the sample fabric is rubbed against a standard fabric until it wears through[35].

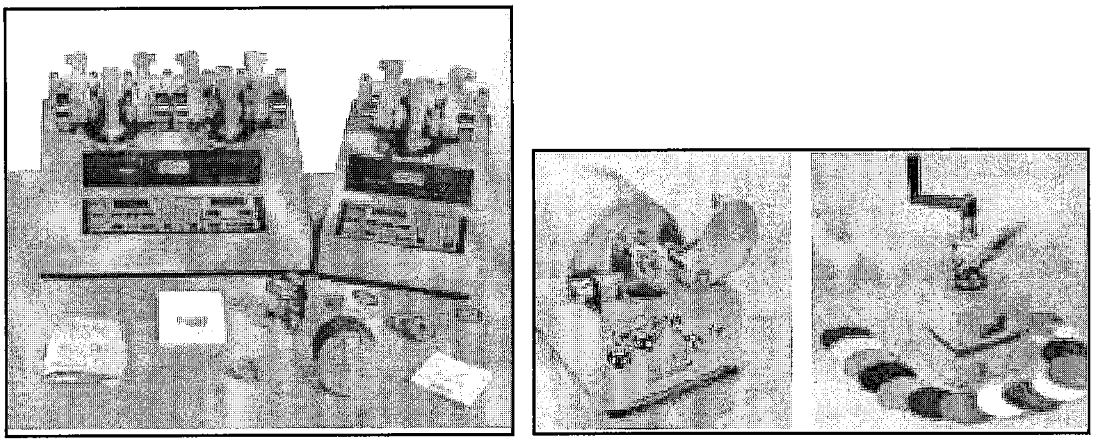


Figure 3.8 Flex abrasion tester

Some international wrinkle recovery tester are:

1) Martindale - BS 5690,
2) JIS L-1096, JIS L-1018 (knit)
3) Accelerator - JIS L-1096 (woven)
4) AATCC 93

3.6.10. Dimensional stability

The dimensional stability test is designed to show how well a fabric keeps its shape after washing, which usually results in shrinkage, although some fabrics can expand, or gain, after washing, for this test, the washing time and temperature, drying procedure and restoration technique (such as ironing) are all specified, and options are available. The sample is measured in both the warp and weft directions (or wales and courses for knitted fabrics). The percentage of shrinkage (gain) is calculated and the results compared with commercially accepted standards.

Wascator AB (Figure 3.9), is a standard, reference washing machine. It is used to determine the stability of fabrics and garments to washing and to investigate the effects of detergents and chemicals[39].

Figure 3.9 Standard washing machine

To determine the stability of fabrics and garments to washing and to investigate the effects of detergent and chemicals. It has an attractive and durable appearance in moderm testing laboratory[35,39].

Some international testing standards are:

1) BS EN 25077, BS 4923
2) ISO 5077, ISO 6330
3) AATCC 135, AATCC 150

3.7. Problems of Knitted Fabrics

Knitted fabric has characteristic faults that occur as a result of the construction of the fabric. They can be categorized into horizontal and vertical components. One type of horizontal fault has already been outlined: that due to different course lengths being incorporated into the fabric.

There are others specific to certain yarn and fibre types, but all these faults characterize themselves as bars across the fabric, of density, color and must be detected in the fabric before incorporation into the garment. Vertical faults usually result from the knitting process but can occur with finishing. Besides general indications and comments it is always necessary to have at least one defective fabric sample for analysis and fault as certainment[39].

In piece goods fabric produced on circular machines it is sometimes possible to split the fabric down a single bad wale line before finishing. Other solutions involve the messy business of removing damaged garment portions from the cut lay and re-cutting.

Such faults in garment blanks or fully fashioned panels render them unusable. In these industries it is much more likely that the knitter in control of the machines would notice them very early, and so prevent much wastage. In most of the cases an experienced technician is needed to examine the conditions on the machine and recommend the proper measures to be adopted[21].

In the terminology normally used one differentiates between the following visible forms of faults in the fabric:

1) cracks or holes,
2) drop stitches,
3) cloth fall-out,
4) snagging,
5) tuck or double stitches,
6) bunching-up,
7) vertical stripes,
8) horizontal stripes,
9) soil stripes,
10) color fly,
11) distorted stitches,
12) wale spirality,
13) pilling,
14) wrinkling,
15) dimensional stability.

This sequence of points is absolutely random. The incorporation of detectable faults into these 15 groups permits an initial judgment[23,40].

3.7.1. Cracks or holes

In daily terminology there is usually no difference made between cracks and holes. It can however be stated that holes are the result of cracks or yarn breakages. During loop formation the yarn had already broken in the region of the needle hook.

Depending on the knitted structure, yarn count, machine gauge and course density, the holes have different sizes. This size can therefore only be estimated if the comparable final appearance of a comparable fabric is known.

Large holes could be caused by weak places in the yarn, leading the yarn to give way or break during loop formation. Small holes are often the result of a broken yarn before or after a knot or splice, since the yarn end with the knot or splice sits tightly in the last stitch. Normally the yarn breaks before the knot or splice, because this gets stuck in the needle or gives rise to a tension peak. Only one loose yarn end can slide out of the loops and the hole can be formed only on one side[41].

For a given knitting speed the ability of the yarn to slide is not sufficient (waxing, moisture and storage). Knots in particular could have too short yarn ends. They can loosen themselves, especially when they are not tight enough. Mechanical knotting can weaken or damage the yarn in the knot. Knots can be too large. These problems are not present in exactly the same manner when splices are present in place of knots.

Yarn take off can be uneven or dragging. The cause could be soft or sticky cones, cones not being centered while creeling (dragging take off, unsuitable yarn brakes and yarn guide elements). The yarn tension is too high in relation to the structure and the breaking strength of the yarn.

The setting of the yarn feeder is faulty in such a way, that a needle can run into the yarn feeder with a closed latch. Through a faulty positioning of the yarn feeder the yarn is clamped between the needle breast and the yarn feeder in such a way that a free yarn movement is not possible[21]. The yarn feeder bore or guide elements can have a run-in surface or have become so edgy, that the yarn is damaged. The stitch cams are so differently set that in basic or jacquard structures the stationary loops are stretched in the following knitting feeders up to break.

The fabric is pulled down too strongly or in jerky movements due to defective setting or bad maintenance. The coulier balance between dial and cylinder cams is not proper. The selected delayed timing in the dial cam occurs before the strain in the cylinder is off. With normal couliering the synchronous needle withdrawal of the dial and cylinder needles is not set precisely[40].

3.7.2. Drop stitches

Drop stitches (runners) are the result of a defective needle. They also occur when a yarn is not properly fed during loop formation, not properly laid in the needle hooks. Depending on the sliding ability of the yarn and the structure selected, drop stitches can run to different lengths into the fabric, which is under the take off tension. With lighter fabrics drop stitches can also be formed in connection with cracks or holes[23].

3.7.3. Cloth fall-out

Cloth fall-out is an area consisting of drop stitches lying side by side. They can occur either when a yarn is laid-out or when it breaks without any immediate connection. The above mentioned points also hold good in connection with the occurrence of cloth fall-out. The yarn is not stitched by several needles lying adjacent to one another. Cloth fall-out can occur after a drop stitch especially when an empty needle with closed latch runs into the yarn feeder and removes the yarn out of the hooks of the following needles[23].

3.7.4. Snags

Snagging occurs almost without exception only while processing continuous filament yarns. Besides the specific sensitivity of these yarns, one main cause is mechanical strain during knitting or subsequent processes. Filaments or yarns have been pulled out of the fabric. If these are not removed properly the connection between courses is broken, and this results in an appearance very similar to cloth fall-out.

As already mentioned, snags mainly occur while processing filament yarns. The tendency towards snagging can be reduced by using yarns with a coarser single filament count, lesser crimp elasticity and higher twist.

During knitting all mechanical influences, caused by rough surfaces on yarn guide elements, yarn feeders, needles, fabric take-up, etc., have to be avoided. Even after knitting some snags can appear especially during fabric setting, if its storage and further processing has not been undertaken carefully[40].

3.7.5. Tuck and double stitches

Tuck or double stitches occur due to badly knitted or non knitted loops. They are unintentional tuck loops or floats, also showing up as thick places or small beads in the fabric. At first instance they may also appear as a shadow when the fabric is observed against light. This fault appears preferably in basic and jacquard structures.

The yarn could be the cause because of its insufficient sliding ability. Needle clearance, if adjustable, is too small. The old loops are not brought safely behind the latch and remain on the spoon[41].

3.7.6. Bunching-up

Visible knots in the fabric are referred to as bunching-up. They appear as beads and turn up irregularly in the fabric. This is largely influenced by the fabric take-up and whether it functions properly.

3.7.7. Vertical stripes

Vertical stripes can be observed as longitudinal gaps in the fabric. The space between adjacent wales is irregular and the closed appearance of the fabric is broken up in an unsightly manner.

Vertical stripes and gaps in the fabric are often the result of a meager setting, i.e., the yarn count selected is too fine for the machine gauge or the stitch size (course density) is not correct. Needles are bent, damaged, do not move uniformly smooth, come from different suppliers or are differently constructed[23].

3.7.8. Horizontal stripes

Horizontal stripes are caused by unevenness in the courses; they traverse horizontally and repeat themselves regularly or irregularly. Horizontal stripes can be caused to the same extent by the yarn or by the setting of the knitting machine. They do not appear that often with worsted wool yarns.

An irregularly striped fabric or a 'fuzzy' fabric is solely the result of irregularities in the yarn. This is also true for uneven dyeing.

Feeder stripes, caused by yarns, can be ascertained by replacing the yarn packages. Fabric appearance alone, without doing such a test, does not indicate whether an uneven yarn or a wrong machine setting can be held responsible. Yarn tension and its fluctuation or a hindrance in yarn delivery are frequent causes. The setting of stitch size and uniform yarn consumption on feeders with similar settings are important pro-requisites[41].

Fabric take-up can also cause horizontal stripes, when a jerky impulse occurs at each machine revolution and take-up is not uniform. Couliering must also be uniform. One must also have the same yarn drawing in ratio between dial and cylinder needles at all feeders.

3.7.9. Soil stripes

Soil stripes can appear both in the direction of wales as well as courses. Color fly consists of single fibres, bunches of fibres or yarn pieces in varying colors. It additionally sticks on the yarn or is knitted into the fabric and is very difficult to remove.

Soil stripes in the direction of the wales are solely caused by the knitting machine. In most cases they are so called needle stripes; they occur when individual needles have been replaced or when the working of mechanical or automatic oiling or greasing devices is defective. Stripes or soiled places in the direction of the courses were already present usually in the yarn, if not caused by a standing course as a result of machine stoppage[21].

3.7.10. Color fly

In this case one must differentiate between three groups:

a) Hairs with natural dark colors, vegetable and food remnants, bast, etc. or similar natural remnants in the case of other fibres. A certain amount of these items are unavoidable and must be tolerated.
b) Fly coming from various processing stages during spinning. It can only be avoided by a careful separation of individual colors during the production.
c) The comments under also hold good for fly in the knitting plant. Especially in plants with a rather congested machine installation and producing color jacquards along with single colored fabrics, or while processing a large number of colors, the danger of color fly is always present[23,40].

3.7.11. Distorted stitches

Distorted stitches lead to a very unsettled fabric appearance. They are most disturbing in single color yarded goods. The fabric appearance is skittery. Such stitches are usually the result of a bad knitting machine setting, especially unequal coulier depths between dial and cylinder needles. If one views the wales, one can then observe that the heads of the stitches are not round (ideal shape) but lopsided. They also appear to have tilted towards the one or the other side[35,41].

3.7.12. Spirality

Spirality is defined as the distortion of a circular knitted fabric in which the wales in the fabric follow a spiral path around the axis of the knitted fabric. In weft knitted fabric produced wit one needle system, the wales are not perpendicular to courses as required but skew to right or left, forming an angle of spirality with the perpendicular. The phenomenon of spirality has been studied by the researchers in several countries over a number of years. But these researches have only defined the principles of spirality and have not totally given a theoretical explanation or solution to solve this problem[42].

The problem of spirality has greatly affected the growth of the knitted fabrics. Some of the distortion resulting from spirality are displacement of seams, miss-match of patterns, sewing difficulties. All these problems greatly effect the production of knitted fabrics when they made into garments. Unlike woven fabrics, knitted fabrics had to first cut in an order such that the spirality can be avoided in the garments. Loop distortion such as spirality degrade the quality of a single jersey knitted fabric. This kind of distortion affects both aesthetics and functional performance of the knitted material and the garments produced from it.

There are several causes of spirality found in the knitted fabrics. One of the causes of spirality is the feed density. Spirality is directly proportional to the number of feeders per inch. That is, the greater the number of feeders on the machine, greater the spirality. As the number of feeders increases, the inclination of the spirality plain will also increase.

Another factor effecting spirality is the direction of the machine rotation. In a multi feed machines, the fabric is created in a helix, which gives rise to course inclination and consequently wale spirality. The wales will be inclined to the right, giving a Z-skew in machines that rotate counterclockwise.

The twist in yarn also affects the spirality in the fabrics. The yarn twist multiple is one of the major reason for the cause of spirality.

There are some solutions to these spirality problems. These solutions do not completely solve the spirality problems, but it eliminates it to some extent. In some cases spirality could be totally eliminated by using a yarn that gives a particular angle of spirality in one direction, and knitting with a number of feeders that would give the same angle of twist in the opposite direction[40].

The factor of twist developed due to the direction can be overcome by the selection of type of twist in the yarn. This deviation can be counter acted by introducing yarns with the same magnitude of spiraling but in the opposite direction, that is, neutralize spirality by knitting S-twist yarn in the machine rotating counterclockwise and Z-twist yarns in machines rotating clockwise[42].

Spirality can also be reduced by feeding alternate feeders with yarns having S-twist and Z-twist respectively.

Spirality can also be eliminated knitting fabrics in a balanced construction, e.g., interlock and balanced ribbed structures. During the formation of these balanced construction fabrics, two sets of needles are used with the loops formed on the front and back needles in alternate wales. In this circumstance, torque in yarns affects the two faces of the fabric in an opposite manner such that the spiral effect on one side of the fabric is counter balanced by that on the other side resulting in a spirality free fabric.

Spirality in a single jersey knitted fabric, arising from the residual yarn torque, can also be indirectly controlled by changing the fabric construction. For example, knitting with yarns which induce spirality of equal magnitude but in opposite direction in alternative courses will reduce spirality. However this technique will give rise to a zigzag effect on the fabric[43].

3.7.13. Pilling

Knitted fabric consumption is increasing all over the world as it enables higher production rates along with lower production costs. Knitted fabrics are also more comfortable, softer and they always have distinctive area in fashion. Beside all these advantages of knitted fabrics, pilling problem slack fabric structure of some knitted fabrics keep being an important objection.

Pilling causes an inightly appearance and also bad handle properties. It is a concern to both textile and apparel manufacturers and consumers because it affects fabric aesthetics and comfort. So it is an undesirable fabric surface default. In addition it has an accelerating effect on the rate of fiber removal from the yarn structure and hence materially reduces the service life[21].

A variety of small mechanical forces disturb the fibres at manufacturing, and also during the life cycle including use, care and maintenance of the fabrics. These forces dislodge or fracture fibres to create lint and fuzz. These forces also roll or twist fibers to cause fibre entanglement that eventually might create pills. Once formed, pills can retain themselves on the surface of a fabric. They also might be disentangled to form lint and fuzz. Disentangled lint and fuzz can move to new locations and might be re-entangled to produce other pills[43].

Fabric pilling is a complex phenomenon comprised of different stages and influenced by several factors. Factors influencing fabric pilling are;

1) The type and size of fibre or fibre mixture used in the component yarn.
2) The construction of the yarn in terms of twist factor.
3) The type and tightness of knitted construction.
4) The nature of the surface against which the knitted fabric has abraded.

The nature of the pills themselves is very interesting; they vary in size, distribution and density. Some only occur on areas of a garment associated with a particular movement, such as on the sides of an upper garment where the arms rub, or sometimes only on the upper chest and upper back where the garment is abraded by an outer garment.

Some pills consist only of fibres from the fabric on which they occur, others are 'robbed' from other garments. Such robbery is associated with fabrics knitted from textured polyester yarns, the abraded surface of which contains very strong fibres capable of entanglement.

This also highlights the fact that some pills are loosely attached and others strongly attached. Wool pills are considered weak and indeed sometimes drop off spontaneously. Pills produced in fabric containing polyamide or polyester fibres are considered strong and persist, making garments on which they occur unsightly and unwearable, even though not worn out.

The problem associated with fuzz can also be eliminated to improve their quality and maintain the quality during the garment life by removing the fuzz, using treatments such as singeing or by applying a surface active agent such as silicon softener to soften the surface of the fabric or by enzymatic bio-polishing. Woven fabrics, as a general rule, are singed to remove protruding fibres and give the fabric a smooth hand and surface appearance. Knit fabrics, on the other hand, are not normally singed or defuzzed. Singeing involves the risk of scorching the fabric whereas the use of surface active agents reduces the water absorbency of the fabric. They are also washed out from the fabric eventually making them rough again. Enzymatic removal of the fuzz is however, absolutely safe, efficient and permanent as it is carried out under mild chemical and physical conditions with accurate control[43].

3.7.14. Folded selvedge

All types of knitting loop have 3-dimension except purl knitted fabrics. Plain fabrics which are produced in single beded machines (RL, single jersey) tends to bend, its because of the moment which is holding the loop in 3-D shape is not balancing the opposite side of direction moments so loops are eagerly come back to its original straight line (yarn has straight formation after knitting it loses this formation) structure. It is called unstable (un balanced) knitting fabrics and edge of the fabrics tends to bend. On the side of the fabrics, edge bending is formed front side to the back, on the top and the bottom of the fabrics, edge bending is formed back side to the front side.

1x1 rib and interlock fabrics which are called double layer fabrics, have the same number of loops at opposite side (both front and back side) so these loops are willingly disengage (break up) but the mutual bending moments are balancing each other and loops are staying together. It is called stable knitting fabrics and in this fabrics no edge bending can be seen.

In rib knitting fabrics; on front side number of loop is marked as ‘m’ and on back side number of loop is marked as ‘n’. If ‘m’ is greater than ‘n’, it is called unstable fabrics and side of the fabrics tend to bend front side to the back.

In some double layer fabrics, loops yarn length is same in both side but number of loop line in front side (because of tuck, etc.) is greater than number of loop line in back side. It is also called unstable fabrics and the top and the bottom of the fabrics tend to bend front side to the back.

Having use of open width fabrics, edge bending of unstable fabrics are caused some problems in finishing and garment process. Having use of tube fabrics during finishing, there is no edge bending can be seen (achieved). But after cutting the fabrics during garment process, some problems can be achieved[40].

3.7.15. Dimensional stability

The most important problems of knitted fabric is the dimensional stability. Dimensional stability is a resistance of physical changes of the knitting fabric.

Knitting is affected by water, heat, moisture and cleaning intensity so under these influences textile materials tends to protect its original shape in length and width.

A fabric or garment may exhibit shrinkage or growth under conditions of refurbishing. Items are especially affected by the moisture and heat used in washing, in tumble drying, and in steaming and pressing[36].

Textile materials are often given shrink resistant finishes to minimize dimensional change. The compacting process of cotton knitted fabrics serves to impart dimensional stability that is resistant to various washing tests. In this way, garments made from the treated fabric will not suffer abnormal shrinkage after initial domestic washing. Compacting of fabrics has therefore become an essential condition for obtaining dimensional stability and for satisfying the various demands of garment makers and the market[43].

Detailed information about the dimensional stability is given in the next chapter.

3.8. Garment Quality

The quality of a knitted garment reflects all the processes through which the various components have passed during its manufacture.

Knitted fabric has already been discussed and the problems of quality outlined. Faults incurred during the knitting and fabric finishing processes pass on into the knitted garment itself unless diverted. During the progress of the fabric or knitted pieces induction system additional faults can be accumulated. The number of possible faults increases with the number of processes that a garment passes through. It follows, therefore, that fully cut garments have the greatest fault potential and some integral garments the least, with stitch shaped cut and fully fashiohed falling in between[21].

A man's sock cannot contain dimensional faults arising from cutting, nor multiple seaming problems. All the faults in a sock can be classified as knitting/yarn or dyeing/finishing. In contrast, on a fully cut garment, a dimensional aberration could be due to the knitted fabric, or the spreading/cutting, or the seaming, or the pressing. It follows that the quality control procedures of the production of fully cut garments need to he comprehensive and at all stages, to avoid cumulative faults.

A brief look at the stages that fully cut garments pass through, with observations on quality control procedures, will uncover most of the peculiarities of knitted garments.

The word quality is sometimes misused in knitted fabric terminology to describe the loop density of a particular fabric. There is no implied judgement of quality about this, only of quantity, i.e. number of loops in a square of prescribed dimensions: loops per square inch or loops per square centimetre[44].

3.9. Fabric Assessment

Knitted fabric is usually examined at two stages: after knitting and after finishing. Quality control procedures are also carried out before and during knitting; before, to set the knitting machine to produce a particular quality, and during to check that the quality is being maintained.

It is arguable that the knitters' main function is quality control, to prevent the knitting machine producing faulty fabric. The rough examination after knitting is to ensure that the fabric is not being produced with visible faults that by feedback can be rectified on a particular knitting machine. Some rough mending may be carried out to prepare the fabric for the dyeing and finishing process[23].

After finishing, the fabric is examined over an examination table, faults are identified and their location marked so that they can be dealt with during spreading or after cutting. Some firms mark only at the selvedge with a colored tag, others locate the actual fault with a sticker as well.

Fault counts can be maintained to assess improving or deteriorating standards. Visual fault location cannot be 100%, neither can an operative act other than subjectively; and checks on the examiners also need to be carried out[21].

CHAPTER 4
DIMENSIONAL STABILITY

4.1. Introduction

The dimensional stability of a fabric is a measure of the extent to which it keeps its original dimensions subsequent to its manufacture. It is possible for the dimensions of a fabric to increase but any change is more likely to be a decrease or shrinkage. Shrinkage is a problem that gives rise to a large number of customer complaints. Some fabric faults such as color loss or pilling can degrade the appearance of a garment but still leave it usable. Other faults such as poor abrasion resistance may appear late in the life of a garment and to some extent their appearance may be anticipated by judging the quality of the fabric. However, dimensional change can appear early on in the life of a garment so making a complaint more likely. A recent survey of manufacturers rated shrinkage as one of the ten leading quality problems regardless of the size of the company[45].

Fabric shrinkage can cause problems in two main areas, either during garment manufacture or during subsequent laundering by the ultimate customer. At various stages during garment manufacture the fabric is pressed in a steam press such as a Hoffman press where it is subjected to steam for a short period while being held between the upper and lower platens of the press.

Laundering is a more vigorous process than pressing and it usually involves mechanical agitation, hot water and detergent. Tumble drying can also affect the shrinkage as the material is wet at the beginning of the drying process, the material being agitated while heated until it is dry. Dry cleaning involves appropriate solvents and agitation; the solvents are not absorbed by the fibres so they do not swell or affect the properties of the fibres. This reduces some of the problems that occur during wet cleaning processes[36].

4.2. Dimensional Change

Dimensional stability refers to a fabric's ability to resist a change in its dimensions. A fabric or garment may exhibit shrinkage (i.e., decrease in one or more dimensions) or growth (i.e., increase in dimensions) under conditions of refurbishing. Items are especially affected by the moisture and heat used in washing, in tumble drying, and in steaming and pressing. Textile materials are often given shrink resistant finishes to minimize dimensional change. There are several types of shrinkage that may occur when textiles are subjected to heat and moisture [34].

4.2.1. Relaxation shrinkage

The international standard for measuring relaxation shrinkage is the determination of dimensional changes of fabric induced by cold water immersion. In the test the strains in the fabric are released by soaking the fabric without agitation in water that contains a wetting out agent. The specimen in conditioned, measured soaked in water, dried, reconditioned and measured again[36].

Relaxation shrinkage results from the relaxation of stresses imposed during weaving or knitting of the fabric. Fabrics are usually stretched during the manufacturing process and, when subjected to conditions that relieve the stresses within the structure, will relax. According to the AATCC definition, relaxation shrinkage can occur when textiles are immersed in water, but are not agitated.

The effect is especially significant in fabrics made of fibers that absorb moisture readily. Hydrophilic fibers absorb water and swell, the magnitude of which depends on yarn and fabric structure. In loosely twisted yarns, there is free space in the yarn for the fibers to swell; but in more tightly twisted yarns, there is free space in the yarn swells with fiber swelling, increasing in diameter.

Relaxation shrinkage is also seen in knitted fabrics. In the knitting process, the loops are pulled in the lengthwise direction and, when the tension is removed, moisture allows them to relax. The loops broaden, shortening the length of the knit and increasing the width. Again an important factor is the moisture regain of the constituent fibers. A 100% cotton knit shrinks more than does a 50/50 cotton/polyester knit.

The mean percentage change in each direction is calculated:

$$\text{Shrinkage} = \frac{(\text{original measurement - final measurement})}{\text{original measurement}} \times 100\% \tag{4.1}$$

In knitted cotton fabrics the shape and orientation of the loops changes as the fibres swell and relax towards their minimum energy conformation. This often occurs without significant changes in knitted loop (stitch) length. The loops usually become rounder in shape (Figure 4.1) causing shrinkage in the wale (length) direction, especially when the fabric has been previously dried under tension. In order to release the stresses imposed by bending twisted yarns into loops, the loops themselves tend to twist out of the plane of the fabric (Figure 4.1). This causes shrinkage in the course (width) direction, and often produces significant differences in twist level in the two legs of the knitted loops[34].

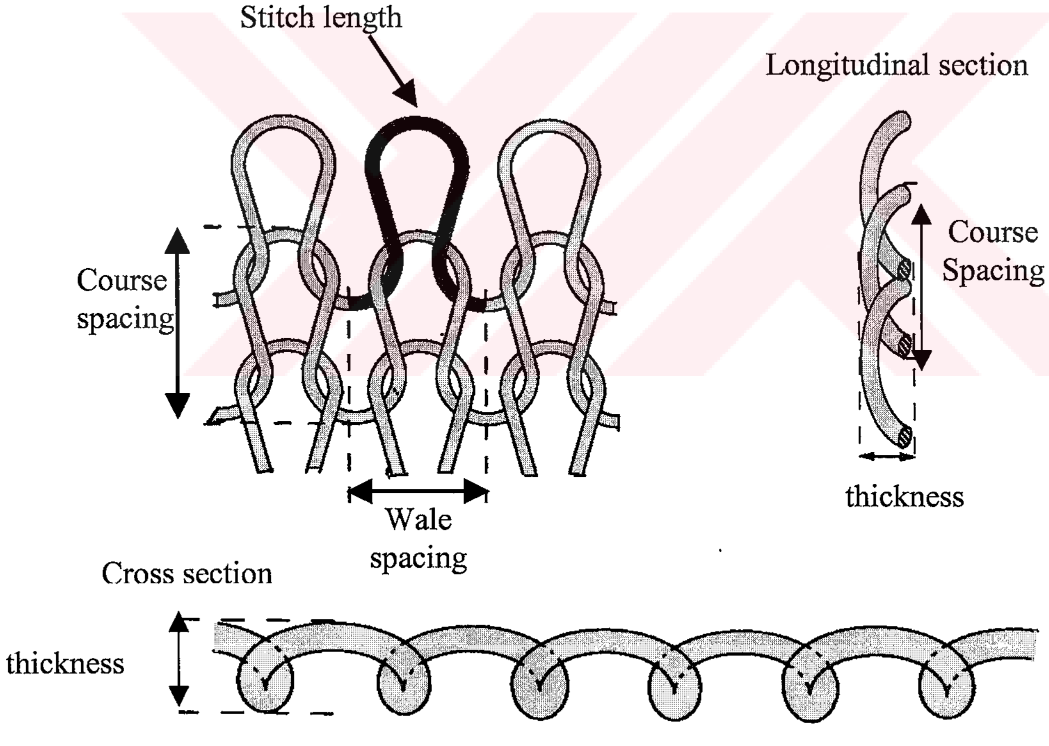


Figure 4.1 Dimensional of a knitted fabric before relaxation shrinkage

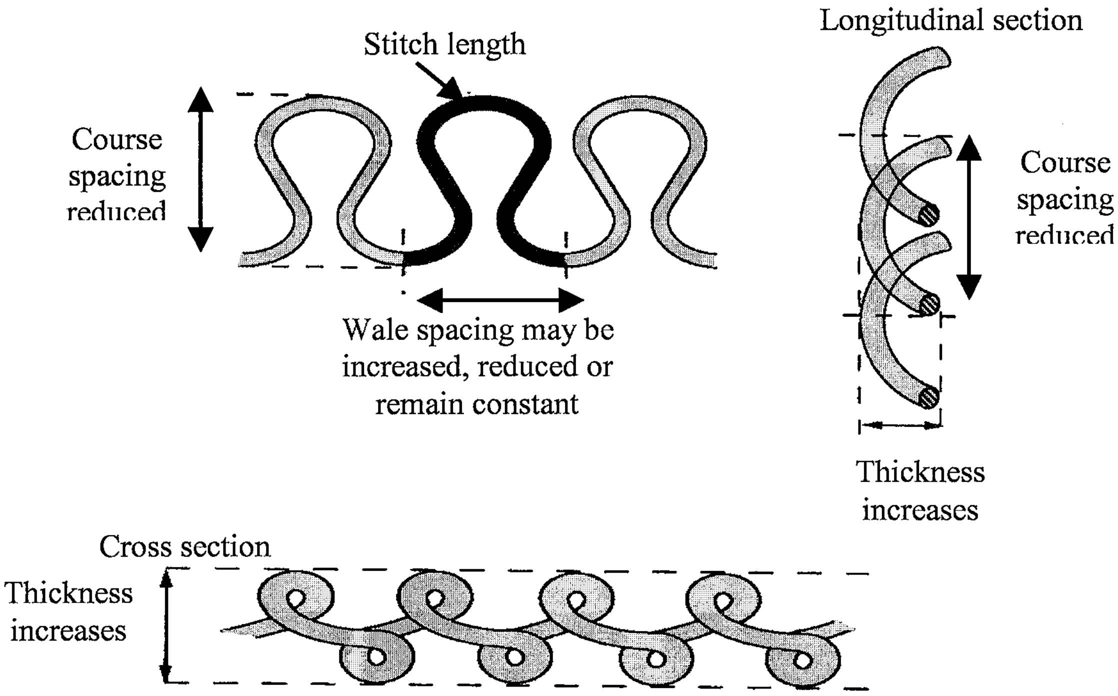


Figure 4.2 Dimensional of a knitted fabric after relaxation shrinkage

Most routine fabric finishing processes, such as scouring, bleaching and dying, allow for some relaxation. However, often these processes include drying of the fabric under tension, which reintroduces strains in the material, to control shrinkage, fabrics can, be given a compressive shrinkage treatment in which they are wetted and then mechanically compressed. Garment finishing or dyeing that is used for some products can also inhibit shrinkage. Stone washing of jeans after construction allows for relaxation shrinkage before consumer use.

In addition to the higher crimping of the yarns that results in fabric dimensional change, the fibers and yarns themselves may shrink. Usually these effects are minimal compared to fabric shrinkage, although increasing the twist in yarns can contribute to yarn shrinkage, when yarns swell, the path of individual fibers around the yarn increases and it will react by relaxing and shortening. This effect is greater in high twist yarns where fibers have a more circular path around the yarn. Crepe fabrics especially those constructed of rayon, usually shrink significantly[34].

Most of the shrinkage due to relaxation occurs with the first washing; a fabric usually relaxes sufficiently during this first laundering although a small amount of additional shrinkage may occur in subsequent washings. That is why many products are preshrunk by the manufacturer to reduce any shrinkage after purchase by the consumer.

Stretching the wet fabric beyond its relaxed dimensions during drying causes relaxation shrinkage in wool fabrics. A proportion of the excess dimensions is retained when the dry fabric is freed of constraint. The fabric will, however, revert to its original dimensions when soaked in water. This effect is related to the hygral expansion value of a fabric in that a fabric with a high value of hygral expansion will increase its dimensions more when it is wetted out so that it subsequently needs to contract to a greater extent when it is dried. Merely holding such a fabric at its wet dimensions will thus give rise to a fabric that is liable to relaxation shrinkage. Except for felts including wool fibers, nonwoven fabrics may show little dimensional change with wetting or laundering. There are several reasons for this: less tension is applied during the fabric forming process and, because they are bonded together with either heat or adhesives, the fibers are prevented from moving very much. Further, most nonwovens have space to allow for fiber swelling so that even nonwovens made of very absorptive fibers, such as rayon, do not shrink much[36].

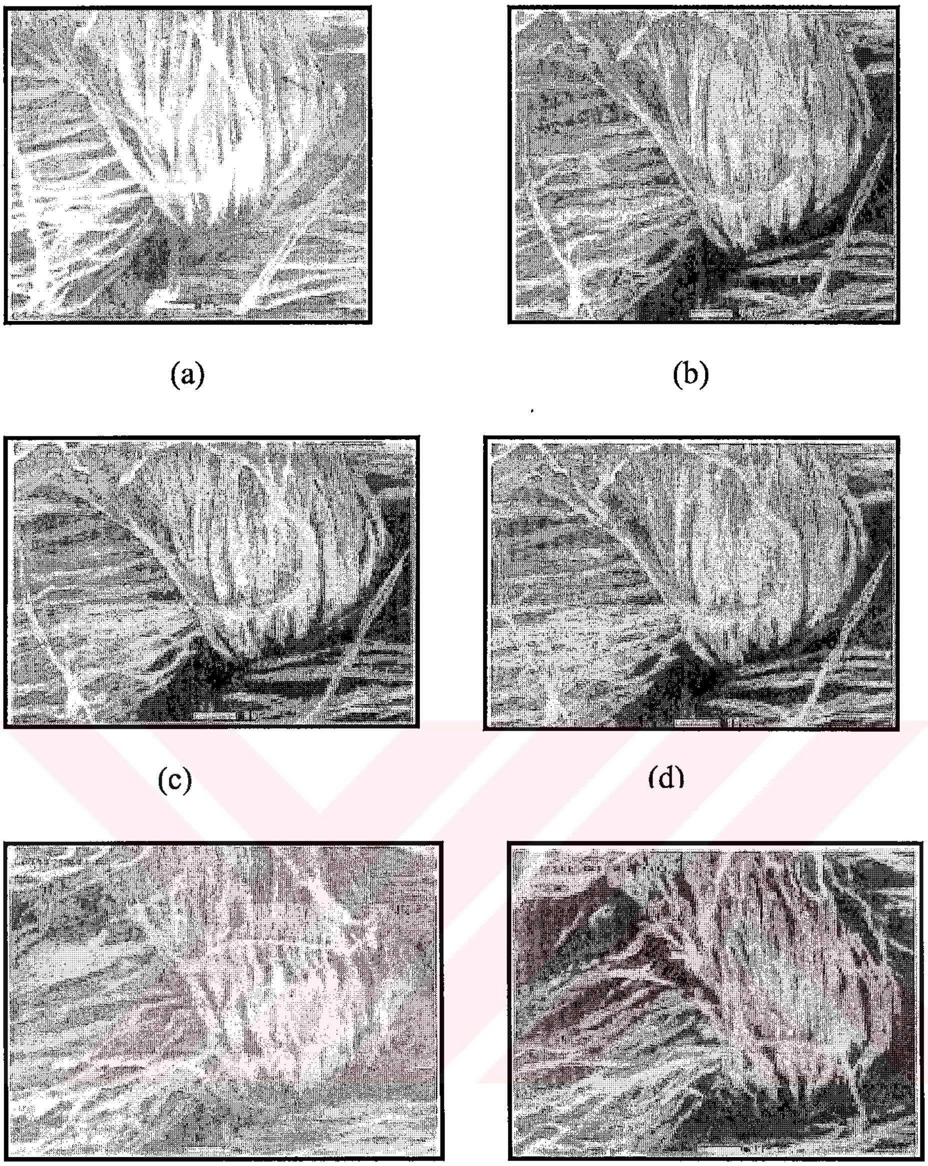
4.2.2. Progressive shrinkage

Progressive shrinkage is dimensional change that continues through successive washings. It occurs when a textile is agitated while it is immersed in water. Unlike relaxation shrinkage, which relieves yarn and fabric stresses, progressive shrinkage usually involves fiber movement within the textile structure. Sufficient agitation in the wetted state overcomes the frictional forces between fibers, allowing the fibers to move relative to each, other. Fibers with a low wet modulus, such as wool and rayon are more susceptible to this type of dimensional change. The fibers extend easily when wet and then retract when dried, becoming entangled and consolidating the structure. This type of consolidation shrinkage can sometimes be purposeful as in the intentional fulling or milling of wools.

The more vigorous the agitation, the greater the shrinkage is. Research some years ago showed that rayon fabrics washed in lighter loads showed more shrinkage than those in heavier loads because less agitation occurs with heavier loads. This is why standard test methods for shrinkage specify the total weight of fabric in the wash load in testing for dimensional change[34].

In tumble drying, the constant agitation of the fabric structure prevents capillary attraction between yarns and fibres from forming inter-fibre adhesions in the structure. Consequently as the fibres de-swell, there is sufficient mobility in the structure for further relaxation to occur. At tumble drying temperatures, intra-fibre hydrogen bonds will not reform until the fabric is almost 'bone-dry'. Consequently, as long as cotton fabrics are removed from the drier before they are completely dry, and before the drier cools down, much of the wrinkling and creasing associated with 100% cotton fabrics can be avoided. Tumble drying accompanied by heat may result in some progressive shrinkage. As the water is driven out of swollen fibers, they collapse, leaving room in the yarn and fabric structure for fiber movement. The mechanical action in tumble drying can promote this fiber movement resulting in a more compact structure[47].

This effect of fiber de-swelling can be seen in Figure 4.3a series of microscopic views of a cotton fabric heated, wetted, and then photographed again after evaporation of the water. A comparison of views in Figures 4.3a and 4.3b, shows that more spaces occur between the fibers after they have been wetted and then dried to drive the water off. Figures 4.3e and 4.3f show that this effect is more significant at higher temperatures. A cotton textile repeatedly washed and dried especially at high temperatures would probably show some progressive shrinkage as the fibers have more room to move. This is especially true for less compact structures. The lower twist yarns and looser construction in knits, for example, may promote this type of shrinkage. A knitted cotton t-shirt would probably exhibit relaxation shrinkage on the first washing as the fabric stresses are relieved and the garment shrinks lengthwise. Subsequent launderings may result in progressive shrinkage due to fiber movement and consolidation[34].



(a) (b)

(c) (d)

(e) (f)

Figure 4.3 Effect of moisture and temperature on cotton fabric: (a) 60°C before wetting, (b) 60°C after wetting and evaporation, (e) 80°C before wetting. (d) 80°C after wetting and evaporation, (e) 100°C before wetting, and (f) 100°C after wetting and evaporation.

4.2.3. Growth

An increase in the dimensions of a textile item can also occur during refurbishing. The most frequent instance is growth in the width of a fabric as it shrinks in length. This is often more pronounced in knitted products. Another consideration is the stretching of fabrics when wet. Those made from fibers with low wet strength, and high elongation extend under certain conditions, such as line drying. Care instructions often recommend that these items be dried flat[19].

4.2.4. Thermal shrinkage

Thermal shrinkage is limited to fabrics composed of thermoplastic fibers, such as acetate, polyester, and nylon. Upon imposition of heat to these fabrics, the polymer molecules in the fibers move and assume a more random, nonlinear form, decreasing their length and shrinking or altering the shape of the fabric. The susceptibility to thermal shrinkage depends on the softening or melting point of the constituent fibers. Because their melting points are lower than other thermoplastic fibers, acetate and olefin fibers are affected at relatively low temperatures, and hot tumble drying can be harmful to fabrics composed of these fibers. A hot iron or drum of a dryer may even melt them, producing holes. Many products made from synthetic fibers are heat-set at high temperatures to prevent this and other types of shrinkage[36].

4.3. Laundering Process

Laundering is based on the use of water as a solvent. Water is effective in dissolving or suspending particulate soils, such as salts, sugar, dust, clay and water-based spots and stains. The agitations, in a washing machine or the rubbing often employed in hand washing provide mechanical action to loosen soil and stains. Higher water temperatures usually enhance cleaning but may have deleterious effects on other properties, such as resistance to dimensional change and color retention. A number of laundering aids may be used to enhance cleaning and alter the appearance or feel of textile items[34].

4.3.1. Standard laundering conditions

Most tests for dimensional change due to washing use the procedures given in BS 4923 or ISO 6330[48]. These standards give in detail the washing procedures for programmable washing machines. The reason that these details need to be specified is that a number of factors affect the intensity of the mechanical action of a rotary drum washing machine such as the peripheral speed of the rotating drum, the height of the liquor in the drum, the liquor to goods ratio and the number and form of the lifters, in particular the height of them. Therefore a standard washing machine has to be used because the amount of agitation during washing has a bearing on the amount of shrinkage produced, particularly with wool. However, the programmes used in the machine are intended to be similar to the programmes found in domestic washing machine. The temperature and severity of the washing cycle used are also related to any care label that may be fixed to a garment made from the fabric being tested. In essence a fabric has to be able to undergo any laundering treatment recommended on the label without suffering from excessive dimensional change.

Washing and drying conditions can affect the dimensional stability of fabrics and garments and, therefore, test methods require that conditions (e.g., water temperature and agitation speed) be specified to provide reproducible results. Several years ago a joint AATCC/ASTM committee developed a standard set of laundering conditions and consistent terminology for use in testing. These are published as a monograph in the AATCC technical manual. Table 4.1 shows the range of wash and rinse temperatures found in current consumer practice and used in AATCC test methods: Table 4.2 gives the settings for washers and dryers. The severity of the mechanical action in washing machines is designated as normal, delicate, or permanent press. "Progressive shrinkage", the amount of agitation can affect dimensional change, and acceptance testing of products should be done as nearly as possible under the same degree of mechanical action[34].

Wash water temperature may have a distinct effect on certain fibers. The photographs in Figure 4.3 show that cotton fibers shrink and curl more at higher temperatures. The water temperature to which the fibers in figure 4.3a were exposed corresponds to the "very hot" temperature in AATCC standard methods. The effects on fibers of hotter, temperatures, such as may occur in commercial laundering, are even more pronounced.

Table 4.1. AATCC standardized washing temperature

	Wash Temperature		Rinse Temperature	
Description	(°C)	(°F)	(°C)	(°F)
Very cold	16±3	60±6	<18	<65
Cold	27±3	80±5	<29	<85
Warm	41±3	105±5	<29	<85
Hot	49±3	120±5	<29	<85
Veryhot	60±3	140±5	<29	<85

Source: AATCC technical manual

Table 4.2. AATCC washer and dryer settings

Setting Washers	Normal	Delicate	Permanent Press
Agitator speed (spm)	179 ± 2	119 ± 2	119±2
Wash time (min)	12	8	10
Spin speed (rpm)	645 ± 15	645 ± 15	430±15
Final spin time (min)	6	6	4
Dryers			
Exhaust temperature (°C)	67 ± 6	62	67±6
(°F)	154±10	<144	154±10
Cool down time (min)	10	10	10

Source: AATCC technical manual.

Most test methods to simulate home laundering require the addition of dummy fabric or ballast to make a full wash load for the samples being tested. This helps to control the amount of agitation to which the test samples are subjected. The construction of ballast fabric is closely specified, with three types of cotton or cotton/polyester fabrics being acceptable.

For tumble drying, the exhaust temperature of the dryer should be specified. In addition to tumble drying test methods for dimensional stability also describe procedures for line drying screen drying, and drip drying. The last method requires that the fabric or textile item be removed from the washing machine before the final spin cycle[34].

4.3.2. Dimensional change in home laundering

AATCC test method 135 (ISO 3759) details procedures for determining the dimensional stability of woven and knitted fabrics; method 150 covers garments. For both methods the appropriate benchmarks are applied and test specimens are placed in an automatic washing machine with the ballast added to make a full wash load of 1.8 kg (4.00lbs). Sixty-six grams of 1993 standard reference detergent are added and the appropriate washing and drying methods selected. After laundering, the textile specimen is conditioned and then remeasured.

Test method 150 (ISO 3759) for garments includes a table of suggested benchmark locations for a number of different garment types so that there is some standardization in measuring. Earlier studies on garment shrinkage had found large variations when measurements were made only between seams: thus, standard benchmarks are recommended. A skirt, for example, should be marked for length, and for hem, hip, and waist dimensions. All of these areas, of course, cannot accommodate benchmarks 50 cm apart, although this length is recommended wherever possible. ASTM standard practices for dress shirts (D 4231), curtains and drapes (D 4721), and bed coverings (D 4721) also give instructions for measuring dimensional changes in these items[45].

4.3.2.1. Domestic laundry processes

Whenever and however domestic washing is done, be it on a riverbank, in a sink, bowl or bucket, or in an automatic washing machine, the principles of the process are the same. Fabrics are saturated with water and agitated or beaten in the presence of products, which are designed to aid wetting, and the breakdown and removal of soils. After squeezing out dirty water, rinsing in clean water (usually several times) and finally squeezing out as much water as possible, the fabrics are dried. Usually at least some of the dry fabrics are finished by pressing or ironing.

In the final rinsing stages, fabric finishing or conditioning products such as softeners, or starch, may be applied, sometimes to selected articles following a common wash process. In most countries, drying is still done mainly by hanging the clothing in the open air, but in Western countries, drying is increasingly being done in tumble driers, where softeners and antistatic agents are often also applied. Thus it is in rinsing, drying and pressing that the domestic launderer seeks to improve the final appearance and handle of the clean washing by applying a variety of finishing techniques[47].

The fabric changes that occur during washing, such as shrinkage, distortion, fibre damage, fabrics becoming stiff and harsh, color fading, and cross-staining by fugitive dyes, are all highly dependent on fibre type, fabric construction, dye class and the fabric finishing processes applied, as well as on the wash process and product. For the purpose of the following discussion, an attempt has been made to separate fabric changes according to:

a) The physical effects of water, temperature and agitation on different fibre types, with some reference to fabric construction, and drying method.
b) The chemical effects of individual ingredients of fabric washing products on different fibre types, with some reference to common fabric finishes.
c) The combined physicochemical effects of the wash process and washing product ingredients, on the colourfastness and cross-staining properties of some of the most commonly used dye class/fibre type combinations.

4.3.2.2. Physical effects of water, temperature and mechanical action on textile fibres

The ways in which water, and variables such as temperature and mechanical action, affects fabrics during domestic washing processes, especially during the first few washes, often depend strongly on the previous history of the fibres, yarns and fabrics, as well as on fabric geometry and the physicochemical properties of the fibres themselves. Consequently, factors such as:

a) Yarn structure and the nature of stresses built into yarns during spinning.
b) Fabric structure and the nature of stresses built into fabrics during knitting or weaving.
c) Physical and chemical effects of scouring, bleaching, mercerising, dyeing and chemical finishing processes.

d) Drying methods, heat setting and mechanical finishing.

These factors may need to be considered when studying the performance of individual fabrics or garments. Since the combination of these variables is different for almost every finished fabric, it is only possible here to identify and discuss those factors that are known to be most relevant to the behavior of important fibre types and fabric constructions under typical laundering conditions[47].

There are a number of different causes of dimensional change, some of which are connected to one another. Most mechanisms only operate with fibre types that absorb moisture, but relaxation shrinkage can affect any fibre type. The following types of dimensional change are general recognised:

a) Hygral expansion is a property of fabrics made from fibres that absorb moisture, in particular fabrics made from wool. It is a reversible change in dimensions which takes place when the moisture regain of a fabric is altered.
b) Relaxation shrinkage is the irreversible dimensional change accompanying the release of fibre strains imparted during manufacture which have been set by the combined effects of time, finishing treatments, and physical restraints within the structure.
c) Swelling shrinkage results from the swelling and de-swelling of the constituent fibres of a fabric due to the absorption and desorption of water.
d) Felting shrinkage results primarily from the frictional properties of the component fibres, which cause them to migrate within the structure. This behavior is normally considered to be significant only for fibres having scales on their surface such as wool.

The dimensions of fabrics can become set while they are deformed if they are subjected to a suitable process. Fibres that absorb water can be set if they are deformed while in the wet state and then dried at those dimensions. Thermoplastic fibres can be set if they are deformed at a comparatively high temperature and then allowed to cool in the deformed state. The set may be temporary or permanent depending on the severity of the setting conditions. During relaxation shrinkage it is temporary set that is released. It is generally the case that deformation that has been set can be released by a more severe treatment than the setting treatment. Conversely if it is wished to make the dimensions of the fabric permanent it is necessary to carry out the setting at conditions that the fabric will not meet in use[36].

4.3.2.3. Mechanical action in washing and tumble drying

The nature of the mechanical action applied in washing processes varies widely across the range of hand wash methods used and the washing machine types available in different countries around the world. It seems reasonable, however, to assume that for any given combination of fibre type and fabric construction, similar changes must occur, but at different rates, according to the mechanical severity of the wash method employed. There have been few comparative studies between different hand wash and machine wash methods, but there is certainly sufficient evidence to show that handwashing cannot be assumed to be generally less damaging than machine washing. Indeed, some hand wash techniques, such as rubbing fabrics on the ribbed concrete surfaces of the typical wash 'tanques' found in many South American countries, are known to be particularly damaging. Similarly the beating of wet fabrics against rocks or walls, or with heavy wooden sticks or bats, as practised in parts of India and Southeast Asia, is also more severe than any washing machine action.

These types of change may be expected to lead to:

a) changes in garment shape and size, and in fabric thickness,
b) fuzzing, pilling, felting and fibre shedding,
c) fibre splitting, fibrillation and breakage.

Mechanical property changes, and associated visual and tactile changes accompany each of these types of change.

4.3.2.4. Physical effects of washing on fibres and fabrics

A fibre swells when it absorbs water, and the swelling shows as a large increase in diameter and some increases in length. As would be expected, fibres which absorb little water tend to swell less than fibres which are very absorbent, although, surprisingly, wool and silk swell rather less than cotton. Regular viscose shows a very high degree of swelling. The swelling of fibres is an important cause of fabric shrinkage during laundering (Figure 4.4)[19].

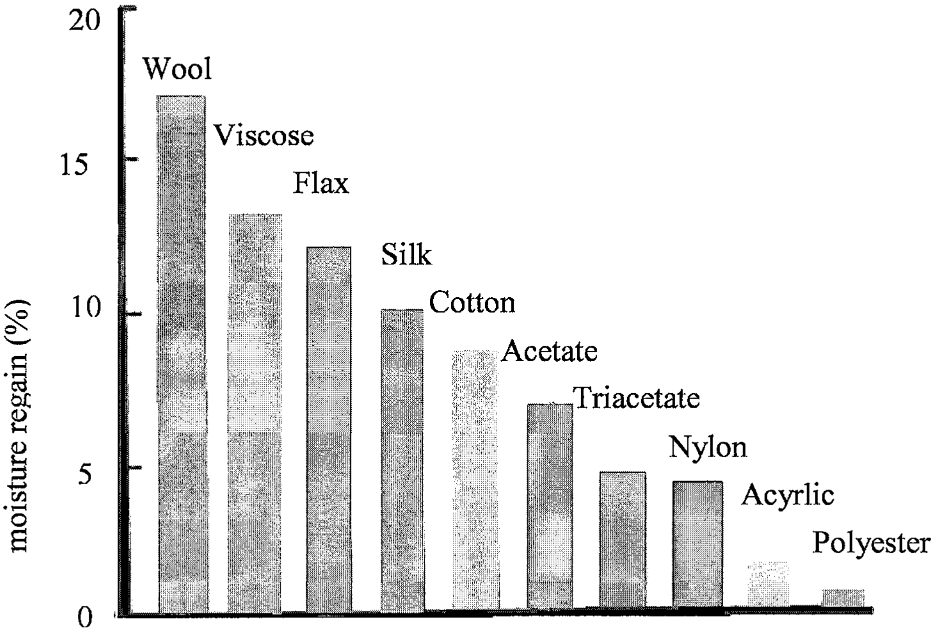


Figure 4.4. Moisture regain fibres

Swelling, shrinking and wrinkling. Cotton fibres swell about 40% by volume in water. This is almost completely accounted for by radial swelling; longitudinal swelling accounting for only about a 1-2% increase in fibre length. This markedly anisotropic swelling behavior is explained by the fact that the crystalline, microfibrillar structures in cellulosic fibres are not penetrated by water. Swelling therefore occurs only between microfibrillar structures, and consequently their orientation in the fibre determines the swelling anisotropy[47].

For regenerated cellulose fibres with their generally lower level of crystallinity, but nevertheless high degree of orientation achieved by the drawing process, swelling is typically in the range of 70-130% by volume with only a 3-5% increase in fibre length.

When fibres are disposed in a spiral configuration as they are in spun yarns it can be shown that radial fibre swelling with no significant increase in fibre length must lead to a reduction in spiral length, and hence to yarn shrinkage. The shrinkage of wet ropes is a familiar manifestation of this phenomenon; when it occurs in textiles, the changes in fabric geometry are complex[47].

4.3.3. Dimensional change in commercial laundering

This test method is used to determine the dimensional changes in woven and knitted fabrics made of fibres other than wool when subjected to laundering procedure commonly used in a commercial laundry. A range of laundering test procedures from severe to mild is provided to allow simulation of the various types of commercial launderings available[49].

AATCC test method 96 (ISO 5077), for stability of woven or knitted fabric in commercial laundering, specifies the use of a wash wheel to simulate commercial equipment. The wash wheel is a metal cylinder with fins or blades on the inside. It has a steam inlet to increase the water temperature rapidly. Temperatures listed are in the range of 41-99°C (i.e., 105-207^{0}F). This range includes temperatures considerably higher than for home laundering. The cotton fibers in figures 4.3e and 4.3f were exposed to temperatures near the top of this range. A variety of drying and after treatments for commercial processes are also included in the test method[34].

4.3.4. Dimensional change in dry cleaning

Although dimensional change is less likely to occur in dry cleaning and, indeed this refurbishing method is often recommended to minimize shrinkage, there may be some effect on particular items. The British standard method [50] requires the use of a commercial dry cleaning machine. In the test the sample is prepared and marked out according to BS 4931(AATCC Method 158)[50]. The total load used is 50 kg for each cubic metre of the machine cage made up of specimen plus makeweights. The solvent to be used is tetrachloroethylene containing 1 g/ℓ of surfactant in a water emulsion, 6.5 litres of solvent being used for each kilogram of load. The machine is run for 15min at 30^{0}C, the sample is rinsed in solvent and then dried by tumbling in warm air. The sample is then given an appropriate finishing treatment, which in most cases will be steam pressing, and it is then reconditioned and measured again. The dimensions of the machine, the solvent and drying temperature, and the load size are all specified in the method. When lined garments or other products are tested, outer fabrics and linings are marked and measured separately to determine any differential effects. A finishing treatment appropriate for the textile item, usually steam pressing, is recommended before the final measurement[36].

4.3.5. Dimensional restoration of fabrics

When a garment or other textile item is to be subjected to some type of force after refurbishing, this treatment must be taken into account in determining dimensional change. An example is a knit shirt that will be stretched when it is put on, or a garment (e.g., body suit) that will have some extensional force applied when it is worn. This force should be small if the garment is to remain comfortable. In addition to stretching, some textile items may require ironing after washing or dry cleaning and this can affect their dimensions. AATCC test method 160 describes a procedure for applying dimensional restoration to textile items after a standard laundering procedure, to simulate the stretching force or pressing they receive before or during use.

For woven and warp knitted fabrics, a tension presser is used. This device applies heat and pressure while fabric is weighted and held in clamps to apply tension in both, length and width directions. A different apparatus the knit shrinkage.

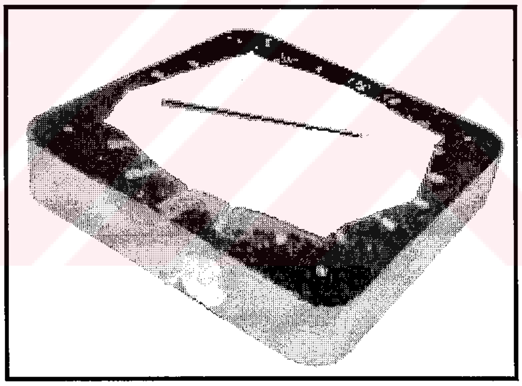


Figure 4.5 Knit shrinkage gauge

Gauge is recommended for restoring weft knits. It stretches the fabric with tension in many directions (Figure 4.5). A final restoration method tat can be used for woven fabrics and garments are hand ironing. This is not a preferred procedure because it is the least reproducible, and should only be used for those fabrics that require ironing in consumer use.

4.4. Refurbishing, Shape and Dimensional Stability

Maintenance of the shape and dimensions of a textile product can be a significant factor in its acceptance by consumers. We are often dissatisfied with a t-shirt that stretches or twists out of shape or curtains that shrink after laundering. Apparel and interior furnishings are exposed to a number of different conditions during use and care that can alter their shape and size. Testing for dimensional change can pinpoint problems likely to occur in consumer use. Testing may also be used to determine the effectiveness of shrink resistant finishes on fabrics.

The general term refurbishing is used to describe any of a number of processes that textiles may undergo to remove soil and stains and to restore the appearance of the items. The two most common refurbishing methods are laundering and dry cleaning. Both involve the use of solvents (water in the case of laundering) combined with some form of mechanical action, and may also include pressing, blocking or other after treatments. The International fabric institute (IFI) provides information on refurbishing and especially on dry cleaning[32].

The user of the product requires dimensional stability particularly in washing and dry cleaning, but it must also be borne in mind that fabric stability during garment manufacture is a pre-requisite for quality merchandise and efficient production management.

The moisture, heat, and agitation to which the products are exposed during laundering or pressing may have deleterious effects, changing not only the dimensions and shape of the textile, but also its appearance or color.

If fabric changes dimensions on the cutting table it will result in the garment parts not being of the correct shapes with consequent mismatching of parts in garment assembly. Check patterns, for instance, may become distorted sufficiently to create problems when matching up the patterns during seaming. Serious dimensional change will affect garment sizing and quality[19].

Steam pressing is another process used in garment manufacture, particularly for outerwear. Here interest centres on ensuring the stability of the fabric in the presence of free steam. Attention will now be directed to an understanding of the causes of fabric shrinkage, since this may provide a better appreciation of the function of finishes applied to control shrinkage.

4.4.1. Shape retention

A change in the dimensions of a textile item, of course, affects its shape, but there are other considerations as well. A common problem with woven and knitted textile products is development of skewness after laundering. Skewness, an element of fabric quality, was described. It results from uneven tensions introduced during weaving or the torsional (i.e., twisting) stresses occurring in knitting processes, especially in weft knitting. Faulty finishing and product construction processes can also produce distortons. The stresses imposed in fabrics or manufactured products can be released under the moisture and heat of laundering. The resulting skewness is undesirable and may even render an item unserviceable.

Two products that are particularly prone to this type of distortion are pants or jeans made from twill fabrics and knitted T-shirts or sweatshirts. Manufacturers of denim jeans have, for some time, received complaints of twisted legs in the garments after washing (Figure 4.6). Knitted shirts and tops also may exhibit twisted seams and distortions in their shape after laundering.

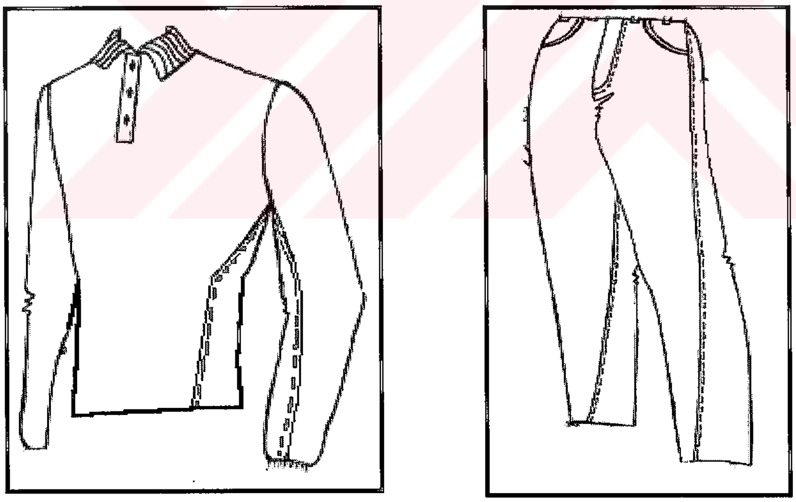


Figure 4.6 Skewness in jeans and shirt

Manufacturers concerned about these problems have investigated process modifications to enhance shape retention in finished products. One method for decreasing skewness in jeans is "pre-distortion" of denim fabric during the finishing process. In this technique, the fabric is intentionally skewed in the tentering frame in the opposite direction of the twill line. The effect is to offset the weaving stresses in the twill direction and inhibit the development of skewness in finished garments.

4.5. Purpose of the Dimensional Stability

When a fabric is stated to lack dimensional stability this usually refers to either shrinkage or extension in one or both directions of the fabric. Fabric shrinkage is a great inconvenience since it may result in a garment becoming too small or too misshapen to wear. There is a slightly greater tolerance of shrinkage in curtain materials since the question of 'fit' is not so critical. Carpets, and carpet tiles in particular, need to be very stable dimensionally once laid to cover the floor area.

Different laundering, dry cleaning, and restoration test methods have been developed to measure the various fabric characteristics affected by refurbishing, including appearance, color, dimensional change, and soil removal. With the rising popularity of cotton, greater demands for quality have been required as end-users have become more aware of its negative properties, and therefore many studies have been reported on the geometry and dimensional properties of knitted fabrics produced from different kinds of yarns. Although the problem of knitted fabric shrinkage can be solved to some extend by replacing 100% cotton with a cotton/synthetic fiber blend yarn, the severity and longevity of piling, dimensional stability, in turn, greatly increases, and dimensional stability has become a much more serious problem for the knitted apparel industry. In addition to an unsightly appearance, pills on a fabric surface initiate garment attrition and cause premature wear[6].

Attention will now be directed to an understanding of the causes of fabric shrinkage, since this may provide a better appreciation of the function of finishes applied to control shrinkage.

To obtain the purpose of the dimensional stability of the knitted fabric:

a) Wearing comfort and fabric appearance.
b) Protect knitted fabrics original shape.
c) Unshrinkable of knitted fabrics.
d) Resistance to flexibility and loose.

For wool the process of unshrinkable and unfelting, for cotton the process of sanforizing, for synthetic the process of fixation obtain the dimensional stability.

4.6. Dimensional Stability of Knitted Fabrics

So far consideration has been given to ways in which fibres affect fabric shrinkage, and to the behavior of woven fabric. Knitted garments have the additional possibility of stretching and 'going out of shape' because the loops can be made to slip and alter shape. In use knitted fabrics are liable to deform under the weight of the garment when it is hung vertically to dry, hence the need to dry, 'dry flat'.

Generally, knitting composed wholly or mainly of thermoplastic fibres can be stabilized by heat setting, but knitted cotton fabrics require special consideration to meet the high standards for outerwear.

The behavior of weft knit cotton fabric arises from the construction details, the manufacturing history during the knitting process, and particularly by fabric finishing. Cotton fabrics for underwear can be compressively shrunk mechanically, somewhat similarly to the sanforizing process. However, the resultant fabric appearance is not of sufficient uniformity and quality to be acceptable for outwear. For outerwear, therefore, greater consideration is given to the specification and control of the knitted structure, particularly in conjunction with subsequent finishing processes. 'Starfish' is a computer-aided system for the prediction of the stability of certain knitted cotton fabrics[19].

4.6.1. Weft knitted fabric relaxation and shrinkage

Changes of dimension after knitting can create major problems in garments and fabrics especially those produced from hydrophilic fibres such as wool and cotton. Articles knitted from synthetic thermoplastic fibres such as nylon and polyester can be heat set to a shape or dimensions which are retained unless the setting conditions are exceeded during washing and wear.

In the case of wool fibres, this effect can be magnified by felting shrinkage. When untreated wool fibres are subjected to mechanical action in the presence of moisture, the elasticity and unidirectional scale structure of the fibres causes them to migrate and interlock into a progressively closer entanglement. Eventually the density of the felted fabric restricts further fibre movement but long before this point the fabric properties, including appearance, will have been severely impaired. Fortunately, it is now possible to achieve a shrink (felting) resist finish in wool yarns during spinning so that, as with cotton yarns, little yarn shrinkage will occur during washing and wearing.

Knitted fabrics tend to change in width and length when taken from the machine, even without yarn shrinkage, indicating a change of loop shape rather than of loop length. During knitting, the loop structure is subjected to tension from sources such as the take down mechanism and in the case of fabric machines the width stretcher board of approximately 15-25 grams per needle. Unless the structure is allowed to relax from its strained and distorted state at some time during manufacture, the more favourable conditions for fabric relaxation provided during washing and wearing will result in a change of dimensions leading to customer dissatisfaction.

In theory, knitted loops move towards a three-dimensional configuration of minimum energy as the strains caused during production are allowed to be dissipated so that eventually, like all mechanical structures, a knitted fabric will reach a stable state of equilibrium with its surroundings and exhibit no further relaxation shrinkage. Unfortunately there are a number of states which may be achieved by different relaxation conditions such as dry relaxation, steaming, static soaking and washing with agitation, centrifuging and tumble drying. These states are difficult to identify, define and reproduce as friction and the mechanical properties of the fibres, yarn, and structure can create high internal restrictive forces and thus inhibit recovery. However, agitation of the knitted structure whilst it is freely immersed in water appears to provide the most suitable condition for relaxation to take place as it tends to overcome the frictional restraints imposed by the intermeshing of the structure.

A satisfactory relaxation technique applied during the finishing of cotton fabric in continuous length form is the compacting or compressive shrinkage technique. The fabric is passed between two sets of roller nips with the feed rollers turning at a faster rate than the withdrawing rollers so that the courses are pushed towards each other and the fabric is positively encouraged to shrink in length. This technique can create difficulties with interlock fabric, which tends to buckle outwards three-dimensionally to produce ripples on the surface known technically.

4.6.2. Dimensional stability of cotton knitted fabrics

Normally dimensional stability is connected with cotton knitted fabrics. Cotton knitted garments shrinks and gets distorted if appropriately not made. It is due to following reasons. Cotton shrinks after washing:

a) due to inherent characteristics of fibre structure the fibre swells in aqueous medium and thus fibre shrinks in length,
b) the tensions built into yarn structure during spinning and knitting are relaxed in aqueous medium, so the fabric shrinks.

Due to the shrinkages, the cotton knitted garments gets distorted in its original dimensions. The distortions further become unbalanced in the garment structure due to handling during garment manufacturing and wear by the users.

Other than washing shrinkage, the other kind of distortion that occurs in knitted fabrics, mainly in garments made from single jersey fabrics, is spirality. Spirality occurs due to lively twists in the yarns, which distorts the wale and courses and the vertical alignment of the fabric is disturbed. To make stable fabrics, we will have to take precautions[52]:

a) to engineer the knitted fabric with correct constructional parameters,
b) to finish the fabrics with appropriate finishing sequence and apparatus.

4.7. Assessment of Dimensional Change

There is no one single method of testing the dimensional change of fabrics. The reasons being that fabrics are composed of different fibre types, and require different washing or dry cleaning conditions. Tests are required also for fabrics that may be exposed to steam during garment manufacture, or may be subject to effects of immersion in cold water. Consequently, a choice of test methods is available, some of which are scheduled as BS or ISO methods. The following test methods. The common procedure for most tests is to cut out flat specimens of a given size from the material and to mark out permanent reference lines.

The distances between pairs of marks are recorded for each direction of the specimen all the specimens are then washed, immersed in water, or dry cleaned as specified, and then allowed to dry and condition horizontally in a tensionless state. Other drying conditions maybe specified, such as line, drip, flat dry, flat-bed press and tumble dry. Calculation of the dimensional change for each fabric direction is derived from the measured length differences, before and after the test, as a percentage of the original length. Shrinkage is indicated by a minus sign and fabric extension by a plus sign. The mean dimensional changes are given separately for each direction. Knitted fabrics may be tested with specimens of double thickness stitched together[19].

4.7.1. Washing stability

Cloth specifications include the maximum permitted level of shrinkage according to what is attainable for the particular fabric or what is required for the intended garment fit. Fabric for most garments is acceptable if it is within the limit of ± 2.5%. Shirts and shirt collars have more stringent requirements and those are set at less than ±1.5%.

Weft knitted fabrics, as already discussed, provide great mobility of fabric structure, hence a maximum shrinkage of 6% or a maximum elongation of 2% may be acceptable. It is however, not uncommon to consider the area rather than linear change when judging the suitability of a knitted fabric. Certain fabrics such as cotton terry towelling may have an 8% limit set for a 60^0C wash.

Reference has been made earlier to the fact that the whole relaxation, shrinkage potential of a fabric may not be realised in a single wash. In subsequent washes further shrinkage may occur in decreasing amouts. For this reason alone it is desirable that screening tests for shrinkage, based on a single wash, should be severe, if they are to ensure satisfactory fabric and garment performance in normal use. A further point to be brought into consideration is that garments often are assembled from several different fabrics and it is very necessary, if garment distortion is to be avoided, that their different components should be of similar stability[19].

4.7.2. Thermal stability

Woven fabrics containing thermoplastic and wool fibres need to be within the limit of 2% shrinkage when tested at say 175^{0}C. This test is carried out by placing the measured specimen between two temperature controlled plates for a given time.

4.7.3. Steam stability

This test is used to predict fabric relaxation shrinkage when steam pressed in garment manufacture. Measured fabric specimens are supported on a metal frame placed inside a chamber and steamed for a total of 90 seconds, following, which the specimens are allowed to condition and are re-measured. Normally shrinkage values of up to 2% and 3% can be considered for woven and knitted fabrics respectively.

4.7.4. Whole garment testing

This method of fabric and garment assessment, in which the garment is washed under controlled conditions in a washing machine, or dry cleaned in a commercial dry cleaning unit, has much to commend it. Any abnormal dimensional change within and between components, and along seams and within collars can be judged subjectively in addition to the assessment of the dimensions of the re-measured garment[21].

4.8. Testing for Dimensional Change

The basic procedure for testing fabrics or garments for dimensional change is measurement of length and width benchmarks before and after a selected refurbishing process. The benchmarks, drawn with indelible ink, are placed 25 cm (10 in) apart, or 50 cm (18 in) for better precision, in each direction. After a standard laundering or dry cleaning method is applied, the marks are remeasured and dimensional change (DC) calculated by:

$$DC\% = \frac{(A - B)}{A} \times 100 \tag{4.2}$$

Where A = original dimension, B = dimension after treatment, DC = dimensional change.

Length and width changes are calculated separately. Growth is reported as positive percentage, while shrinkage is reported as a negative number. Specimens are conditioned according to ASTM standard D 1776 (AATCC 150, ISO 3759) before each measurement[34,36].

CHAPTER 5
EXPERIMENTAL STUDY

5.1. Introduction

Knitted fabrics are constructed by the interlocking of a series of loops made from one or more yarns, with each row of loops caught into the preceding row. Knitted fabrics were formerly described in terms of the number of courses and wales per unit length and the weight of the fabric per unit area.

Three basic stitches are used to make weft knitted fabrics: plain, purl and rib. The plain knitted fabrics (single jersey) are produced with one set of needles using a flat or circular knitting machine. These fabrics are used extensively in manufacturing jumpers, hosiery and underwear fabrics. Rib knitted fabrics are produced using two sets of needles, generally situated at right angles to one another to allow greater variety of fabric design. The rib structure gives a fabric a fair degree of elasticity in width, a characteristic that lends itself to producing meets socks and underwear as well as the wrist and neck bands for jumpers. Purl knits are a combination of plain and rib stitches and can be produced on both circular and flat bed knitting. The fabric extends easily lengthwise and crosswise and for this reason is commonly used for childrens wear, such as jumpers.

During use or refurbishing, fibers, yarns or fabrics of various structures change their dimensions. This kind of distortion, especially in knit fabrics is of equal concern to the fabric manufacturer, retailer, garment maker, and consumer. It has also been one of the most extensively discussed subjects in both industry and research.

Due to the influence of fashion, the production of knitted goods has been expanded, with new fabric designs created with different fiber blends and knit structures. The effect of the former on fabric shrinkage was extensively investigated in various combinations, but so far as the latter is concerned there is still a lack of information in the literature.

Dimensional change of fabrics, especially due to repeated laundering, is a critical attribute and, hence, its accurate quantification is a major concern for all sectors of the textile industry.

During the knitting process, the yarns forming the fabrics are constantly under stress. As a result, the fabric on machine is more distorted than its natural relaxed state. When the fabric is removed from the machine, it has time to relax and overcome these stresses, a form of relaxation that is easily recognizable by the changes in dimensions.

Our further aims in this work are to examine the ways in which the conditions chosen for domestic laundering can affect the mechanical and sensory properties of knitted fabrics over a large number of wash cycles, and to identify and damaging aspects of the laundering process for individual fiber types. Some definations related with dimensional change are given below;

a) **Dimensional change**; generic term for changes length or width of a fabric specimen subjected to specified conditions. The change is usually expressed as a percentage of the initial dimension of the specimen.
b) **Growth;** dimensional change resulting in an increase or a decrease of length or width of a specimen.
c) **Laundering;** of textile materials a process intended to remove soils and/or stains by treatment (washing) with an aqueous detergent solution and normally including rinsing, extraction and drying.
d) **Shrinkage;** dimensional change resulting in a decrease in the length or width of a specimen.

5.2. Principle and Purpose

Dimensional stability affects fit, size, appearance and suitability for end use. Therefore, it is an important aspects of consumer satisfaction. Dimensional change refers to differences in dimensions of a material, component, or product during finishing, manufacturing or care. The most common dimensional change is shrinkage. Changes occur because tensions in some materials that developed during yarn spinning, fabrication and finishing may be relaxed when a material is wetted and dried without tension. Poor dimensional stability can also affect fabric density and drape. For instance, materials may become more compact and stiff when they shrink. Dimensional change of fabrics, especially due to repeated laundering, is a critical attribute and hence its accurate quantification is a major concern for all sectors of the textile industry.

5.2.1. Standards in use

In order to achieve reproductibility standard methods are developed. The standards which were followed for the experimental studies are given below;

1) AATCC 135-ISO 3759 “Dimensional changes in automatic home laundering of woven and knit fabrics”.
2) TS 5720-EN ISO 6330 “Textiles-domestic washing and drying procedures for textile testing”.
3) TS 392-EN ISO 25077-ISO 5077 “Textiles-determination of dimensional change in washing and drying”.
4) TS 240-EN ISO 20139 “Textiles-standard atmospheres for conditioning and testing”.
5) TS 4073 EN ISO 3759 “Textiles, preparation, marking and measuring of fabric specimens and garments in tests for determination of dimensional change”.
6) ISO 13934-1, 13934-2 “Textiles, tensile properties of fabrics: determination of maximum force and elongation at maximum force using the strip method. Determination of maximum force using the grab method”.

5.2.2. Apparatus and materials

The apparatus and materials used in the experimental studies are;

a) Automatic washing machine.
b) Automatic tumble dryer.
c) 1993 AATCC Standart reference detergent.
d) Ballast of 92x92 cm (36x36 in.) hemmed pieces of bleached cotton sheeting (wash load ballast type 1), 50/50 polyester/cotton bleached an mercerized poplin (wash load ballast type 2), or 50/50 polyester/cotton bleached mercerized plain weave (wash load ballast type 3).

e) Indelible ink marking pen for use with suitable rule, tape, marking template, or other marking device.
f) Measuring devices.
g) Standard in use for this test" TS 5720 EN ISO 6330 Textiles-domestic washing and drying procedures for textile testing".

5.2.3. Test procedures

The dimensional changes of fabric specimens subjected to procedures typical of home laundering and drying practices are measured using pairs of bench marks applied to the fabric before laundering.

5.2.3.1. Sampling and preparation

The general procedures for preparing and marking out of samples is laid down in the ISO standard. Many dimensional stability tests follow very similar lines differentiated only by the treatment given to the fabric, so that these procedures may be followed if no specific test method exists.

5.2.3.2. Measuring and marking out samples

For critical work the recommended sample size is 500mm x 500mm and for routine work a minumum sample size of 300mm x 300mm is considered sufficient. Specimens are prepared as 500mm x 500mm dimensions. The samples are marked with three sets of marks in each direction, a minumum of 350 mm apart and at least 50mm from all edges as shown in Figure 5.1. All samples are then conditioned in the standard atmosphere. After measurement the samples are subjected to the required treatment and the procedure for conditioning and measurements repeated to obtain the final dimensions.

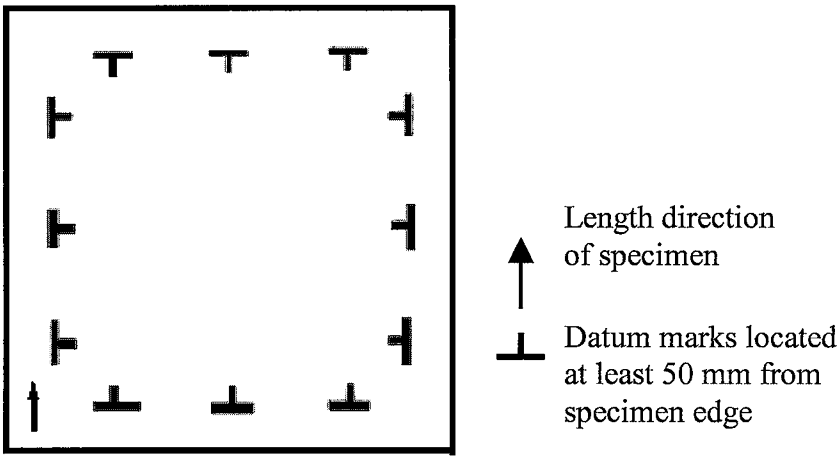


Figure 5.1 Measurement of dimensional change of fabric

5.2.3.3. Washing and drying process

Specified water level was used and the selected water temperature for the washing cycle and a rinse temperature uses less than $29^{o}C(85^{0}F)$. Standard reference detergent was addes for 66±1 g of 1993 AATCC. Test specimens and enough ballast to make a 1,8±0,1 kg (4.00±0,25lb) load. Finally the washer was set for the selected washing cycle and time.

Tumble dryer was used for drying purpose. The washed load (test specimens and ballast) was loaded in the tumble dryer. The dryer was operated until the total load was dry. The load was removed immediately after the machine stop.

The mechanically induced changes occurring in textiles during washing and tumble drying processes may result from:

a) movement of yarns relative to one another,
b) migration of fibres within yarns,
c) damage to individual fibres by abrasion and beating,
d) abrasive wear of fabric to fabric,
e) abrasive wear of fabric to machine parts.

5.2.3.4. Conditioning and restoration

After the completed washing and drying interval, precondition and condition were applied to specimens for at least 4 hr by laying each specimen separately on the screen or perforated shelf of a conditioning rack in atmosphere of 21 ± 1^0C (70 ± 2^0F) and 65 ±2 %RH.

5.2.3.5. Measurement

The distances between three point of bench marks were measured and recorded to the approximately 0,1% values width and length. After conditioning, each test specimen was laid without tension on a flat smooth, horizontal surface. The distance between each pair of bench marks was measured and recorded.

5.2.3.6. Calculation

Calculation of dimensional stability were done according to the following equation;

$$DC\% = 100(A - B)/A \tag{5.1}$$

where:

DC = Dimensional change, A = Original dimension, B = Dimension after laundering.

Both original and final dimensions are the averages of the measurements in each direction made on the three test specimens. Length and width averages was calculated separately to nearest 0.1%.

A final measurement smaller than the original measurements results in a negative dimensional change which is shrinkage. A final measurement larger than the original measurement results in a positive dimensional change which is growth or negative shrinkage. The specification of all fabrics which were used in experimental studies are given in Table 5.1.

In this study cotton, polyester and acrylic fibers are used as a raw material to obtain dimensional stability of fabrics. Specific properties of these fibers are given on table 5.2. All values are classified by world standarts on this table[26-53].

Table 5.1. Test samples and specifications

	Fabric Structure	Fabric Composition	Fiber Fineness(mic.)	Fiber Length(mm)	Yarn Count(Ne)	Twist (tpm)	ring/ rotor	Courses/ Wales (cm)	Diameter (in.)
1	**Plain**	100% Co	4,6	30,5	30/1	800	ring	14/9	32
2		100% Co	5	29,5	30/1	800	rotor	14/9	30
3		100% Co	4,3	29,5	30/2	800	ring	15/11	30
4		100% Co	4,3	29,5	30/2	800	rotor	15/11	30
5		100% Co	5	29,2	20/1	650	ring	14/9	30
6		100% Co	4,5	30	20/1	650	rotor	14/9	30
7		100% Co	5	30	20/2	650	ring	15/11	30
8		100% Co	4,5	30	20/2	650	rotor	15/11	30
9		50%Co+50%Pac	4,5	29,5	30/1	800	rotor	14/9	30
10		50%Co+50%Pes	4,5	29,5	30/1	800	rotor	14/9	30
11	**Rib**	100% Co	4,5	30	30/1	800	ring	14/9	32
12		100% Co	4,4	29	30/1	800	rotor	14/9	32
13		100% Co	4,3	29,5	30/2	800	ring	15/11	30
14		100% Co	4,4	29,5	30/2	800	rotor	15/11	30
15		100% Co	4,5	29	40/1	900	ring	14/9	30
16		100% Co	4	29	40/1	900	rotor	14/9	30
17		100% Co	4,5	29	40/2	900	ring	15/11	30
18		100% Co	4	29	40/2	900	rotor	15/11	30
19		50%Co+50%Pac	4,3	29,5	30/1	800	rotor	14/9	32
20		50%Co+50%Pes	4,3	29	30/1	800	rotor	14/9	32
21	**Lacoste**	100% Co	4,3	29,5	30/1	800	ring	14/9	32
22		100% Co	3,8	29	30/1	800	rotor	14/9	32
23		100% Co	4,3	29,5	30/2	800	rotor	14/9	30
24		100% Co	3,8	29	30/2	800	ring	14/9	30
25		100% Co	4	29	40/1	900	rotor	14/9	30
26		100% Co	4,5	29	40/1	900	ring	14/9	30
27		100% Co	4	29	40/2	900	rotor	14/9	30
28		100% Co	4,5	29	40/2	900	ring	14/9	30
29		50%Co+50%Pac	4,3	29,5	30/1	800	rotor	14/9	30
30		50%Co+50%Pes	4,3	29	30/1	800	rotor	14/9	30

Note: Some values are rounded to the nearest upper or lower values.

Table 5.2.Fiber characteristic properties of cotton, polyester and acrylic fibers

Type of fiber	Fiber Strength (g/d)		Elongation at Break (%)		Absorbency Moisture Regain (%)	Specific Gravity (g/cc)	Fiber Fineness (dtex)	Fiber Length (mm)
	Dry	Wet	Dry	Wet				
Cotton	3.5 - 4.0	4.5 - 5.0	3.0 - 7.0	9.0 - 10	7.0 - 11	1.52 - 1.54	1.6 - 2	25 - 30
Acrylic	2.0 - 3.0	1.8 - 2.7	35 - 45	41 -50	1,0 - 1,5	1.14 - 1.19	0.6 - 25	38 - 200
Polyester	2.4 - 7.0	2.4 - 7.0	12 -55	12 -55	0.3 - 0.5	1.34 - 1.38	0.6 - 44	38 - 200

5.3. Dimensional Stability of Knitted Fabrics

Our main objective in this study is to investigate the effects of some yarns and fabrics variables of the dimensional changes, breaking strength and also breaking elongation properties of plain, rib, lacoste, knitted fabrics. Also, how similarly constructed cotton and cotton blends knitwear fabrics were subjected to up to ten laundering cycles in a variety of washing and drying conditions were described.

5.3.1. Plain knitted fabrics

In the simplest fabric construction all the units are of the same sort, i.e. each loop is the shape and is pulled through the previously knitted loop in the same manner or direction. The simplest fabric is called plain weft knitted fabric, usually abbreviated to plain fabric. Because all the loops intermesh in the same direction the fabric has a different appearance on each side. The side to which the loops appear pulled through is known as the ‘face’ or ‘technical face’. The side from which the loops appear pushed away is known as the ‘back’ or ‘technical back’.

5.3.1.1. Dimensional changes plain knitted fabrics

Dimensional changes in the widthwise direction of the plain knitted sample fabrics produced from different yarns and fibers are given in Figure 5.2. As seen on the figure that each sample represents different shrinkage values. Another important factor that effect the dimensional stability is the fiber fineness. In this study fibers whose fineness change between 4-5 micronaire are used. The effect of the fineness of the fibers on the dimensional stability could not examined in this study because fiber fineness values are very close to the each other. There are also other several parameters which may effect the dimensional stability. A detailed analysis were made on those parameters. Namely;

a) fiber blend,
b) yarn count,
c) yarn twist,
d) yarn production method,
e) yarn ply,
f) fiber length,
g) fabric structure.

As a first test plain knitted fabrics, having same properties but different fiber blend ratios, are tested to examine the effect of fiber blending on the dimensional stability of fabrics. The test results give the following shrinkage values after tenth subsequent laundering and drying processes;

i) fabric made of Ne 30/1 rotor yarn 100% Co. =13.8%
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =8.3%
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =7.9%

The shrinkage values of the fabrics show that fiber blend plays an important role on the dimensional stability. Blending of cotton with polyester or acrylic by 50% may improve the dimensional stability as much as 42%.

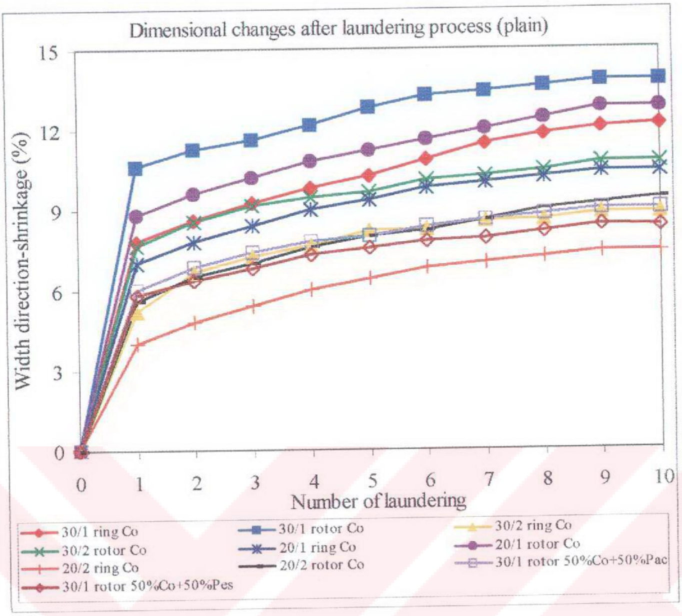


Figure 5.2 Widthwise direction dimensional changes of plain knitted fabrics related to laundering process

Another factor is the yarn counts. The following fabrics are compared to investigate the effect of yarn counts on the dimensional stability;

i) fabric made of Ne 30/1 ring yarn 100% Co. =12.1%
ii) fabric made of Ne 20/1 ring yarn 100% Co. =10.4%
iii)fabric made of Ne 30/1 rotor yarn 100% Co. =13.8%
iv) fabric made of Ne 20/1 rotor yarn 100% Co. =12.8%

Calculations indicate that reducing the yarn count from Ne 30 to Ne 20 may improve the dimensional stability of fabrics approximately 11%. Other words, there is an inverse relationship between yarn count and shrinkage ratios.

The third parameter to be investigated is the twist factor, however there is a close relationship between yarn count and the yarn twist. Because, the number of twist/meter is adjusted to optimize the tension in the fibers and to prevent excessive snarling of the yarns. The shrinkage normally happens by swelling of fibers due to water or moisture that causes shrinkage in the length of the fibers. So there is a relationship between fiber length and shrinkage. A similar relationship may be raised between untwisted length of the yarn and the shrinkage. However, twisting of the fibers to produce a yarn will reduce the length of the yarn. More twist means shorter the length of the yarn. In other word, increasing the twist factor will increase the shrinkage. That means, in fact, the fineness of a yarn has no effect on the shrinkage but it seems that coarse yarn causes lower shrinkage and finer yarn causes higher shrinkage, this is due to twist difference between coarse yarns and fine yarns. Therefore, coarse yarns may be compared with fine yarns under same situations to see the effect of twist factor on the shrinkage. The shrinkage values of the fabrics are given below;

i) fabric made of Ne 30/1 ring yarn 100% Co. (800 turns/m) =12.1%
ii) fabric made of Ne 20/1 ring yarn 100% Co. (650 turns/m) =10.4%
iii) fabric made of Ne 30/1 rotor yarn 100% Co. (800 turns/m) =13.8%
iv) fabric made of Ne 20/1 rotor yarn 100% Co. (650 turns/m) =12.8%

These results are the same results which are obtained from the comparison of yarn counts on the shrinkage. So, it means that the yarn count and the twist factor are the same parameters.

Yarn production methods have also some effects on the shrinkage ratio of fabrics since the orientations of fibers in yarns depend on their spinning methods. Different fabrics made of ring and rotor spun yarns are compared to see the effects of yarn production methods. The fabrics types and their shrinkage results are given below;

i) fabric made of Ne 30/1 ring yarn 100% Co. =12.1%
ii) fabric made of Ne 30/1 rotor yarn 100% Co. =13.8%
iii) fabric made of Ne 20/1 ring yarn 100% Co. =10.4%
iv) fabric made of Ne 20/1 rotor yarn 100% Co. =12.8%

The above results clearly show that the fabrics produced from rotor spun yarns exhibit more shrinkage than the fabric produced from ring spun yarns, however the difference gets larger for fabrics produced by coarser yarns.

Yarn ply is another important factor that affects the shrinkage ratio of the fabrics.The first assumption is that the fabrics produced from plied yarns will exhibit similar results to that of fabrics produced by single yarns, since both yarns have same counts and same twist number. However, interestingly, the plied yarns cause less shrinkage with respect to the fabrics of single yarns. The shrinkage values of the following fabrics are compared;

i) fabric made of Ne 30/1 ring yarn 100% Co. =12.1%
ii) fabric made of Ne 30/2 ring yarn 100% Co. =8.9%
iii) fabric made of Ne 20/1 ring yarn 100% Co. =10.4%
iv) fabric made of Ne 20/2 ring yarn 100% Co. =7.4%
v) fabric made of Ne 30/1 rotor yarn 100% Co. =13.8%
vi) fabric made of Ne 30/2 rotor yarn 100% Co. =10.7%
vii) fabric made of Ne 20/1 rotor yarn 100% Co. =12.8%
viii) fabric made of Ne 20/2 rotor yarn 100% Co. =9.4%

The results show that the fabrics produced by single yarns have more shrinkage than the fabrics produced by plied yarns. The difference may change between 24% - 28% depending on the fineness of the yarn and the yarn production methods. The reason of the less shrinkage of plied yarns may be the denser structure of the fabrics because two yarns are fed to each needle during the production of fabrics.

The effect of the length of the fibers on the shrinkage could not examined in this study because all the fabrics have approximately similar length of fibers (29-30 mm). The effects of fabric structures will be examined at the end of this chapter.

Dimensional changes in the length direction of the plain knitted sample fabrics produced from different yarns and fibers are given in Figure 5.3. Plain knitted fabrics, having same properties but different fiber blend ratios, are tested to examine the effect of fiber blending on the dimensional stability of fabrics. The tested fabrics exhibit the following shrinkage values after ten subsequent laundering and drying processes;

i) fabric made of Ne 30/1 rotor yarn 100% Co. =13.6%
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac =7.5%
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =7%

As seen from the above results fiber blend was an important effect on the dimensional stability. Blending of cotton with polyester or acrylic by 50% may improve the dimensional stability as much as 47%.

The following fabrics are compared to investigate the effect of yarn counts that is on another factor on the dimensional stability.

i) fabric made of Ne 30/1 ring yarn 100% Co. =%12.7
ii) fabric made of Ne 20/1 ring yarn 100% Co. =%10.2
iii) fabric made of Ne 30/1 rotor yarn 100% Co. =%13.6
iv) fabric made of Ne 20/1 rotor yarn 100% Co. =%11.8

Calculations indicates that reducing the yarn count from Ne 30 to Ne 20 may improve the dimensional stability of fabrics approximately 16%. It's clear from the results that there is an inverse relationship between yarn count and shrinkage ratios.

In lengthwise direction twist factor and shrinkage, also show similar relationship with widthwise direction. In lengthwise direction the shrinkage values of the fabrics are given below;

i) fabric made of Ne 30/1 ring yarn 100% Co. (800 turns/m) =12.7%
ii) fabric made of Ne 20/1 ring yarn 100% Co. (650 turns/m) =10.2%
iii) fabric made of Ne 30/1 rotor yarn 100% Co. (800 turns/m) =13.6%
iv) fabric made of Ne 20/1 rotor yarn 100% Co. (650 turns/m) =11.8%

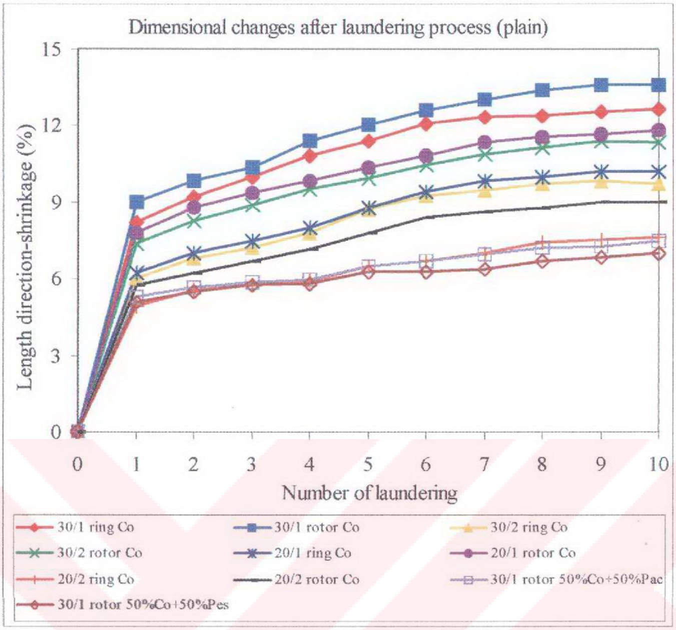


Figure 5.3 Lengthwise dimensional changes of plain knitted fabrics related to laundering process

In lengthwise the shrinkage results of fabrics made of ring and rotor spun yarns are given below;

i) fabric made of Ne 30/1 ring yarn 100% Co. =12.7%
ii) fabric made of Ne 30/1 rotor yarn 100% Co. =13.6%
iii) fabric made of Ne 20/1 ring yarn 100% Co. =10.2%
iv) fabric made of Ne 20/1 rotor yarn 100% Co. =11.8%

The above results clearly show that the fabrics produced from rotor spun yarns exhibit more shrinkage than the fabric produced from ring spun yarns, however the difference gets larger for fabrics produced by coarser yarns.

Yarn ply is another important factor that affects the shrinkage ratio of the fabrics. The shrinkage values of the following fabrics are compared;

i) fabric made of Ne 30/1 ring yarn 100% Co. =12.7%
ii) fabric made of Ne 30/2 ring yarn 100% Co. =9.7%
iii) fabric made of Ne 20/1 ring yarn 100% Co. =10.2%
iv) fabric made of Ne 20/2 ring yarn 100% Co. =7.6%
v) fabric made of Ne 30/1 rotor yarn 100% Co. =13.6%
vi) fabric made of Ne 30/2 rotor yarn 100% Co. =11.3%
vii) fabric made of Ne 20/1 rotor yarn 100% Co. =11.8%
viii) fabric made of Ne 20/2 rotor yarn 100% Co. =9.0%

As seen from the above results single yarns have more shrinkage than the fabrics produced by plied yarns. The difference may change between 20%-27% depending on the fineness of the yarn and the production method.

5.3.1.2. Change in breaking strength

In plain knitted fabrics, breaking strength and breaking elongation tests are also made between washing cycles. Plain knitted fabrics widthwise direction and lengthwise direction breaking strength with respect to laundering process are given on Figure 5.4 and 5.5.

First of all breaking strength values are investigated with respect to yarn ply and yarn count. The test results are given below after tenth subsequent laundering and drying process;

i) fabric made of Ne 20/2 ring yarn 100% Co. =35.5 kg
ii) fabric made of Ne 20/1 ring yarn 100% Co. =21.0 kg
iii) fabric made of Ne 30/2 ring yarn 100% Co. =31.1 kg
iv) fabric made of Ne 30/1 ring yarn 100% Co. =20.2 kg

The results clearly show that the fabric produced by plied yarns have 38% higher breaking strength values than the fabric produced by plied yarns. The higher the yarn count, results better breaking strength values.

Raw material is another important factor that effects the breaking strength values. The first assumption is all fabrics have same yarn counts and same specifications just raw material of fabrics were changed. The breaking strength values of following fabrics are compared;

i) fabric made of Ne 30/1 rotor yarn 100% Co. = 11.8 kg
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =15.1 kg
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =18.4 kg

Blending of cotton with polyester or acrylic by 50% may improve the breaking strength as much as 30%.

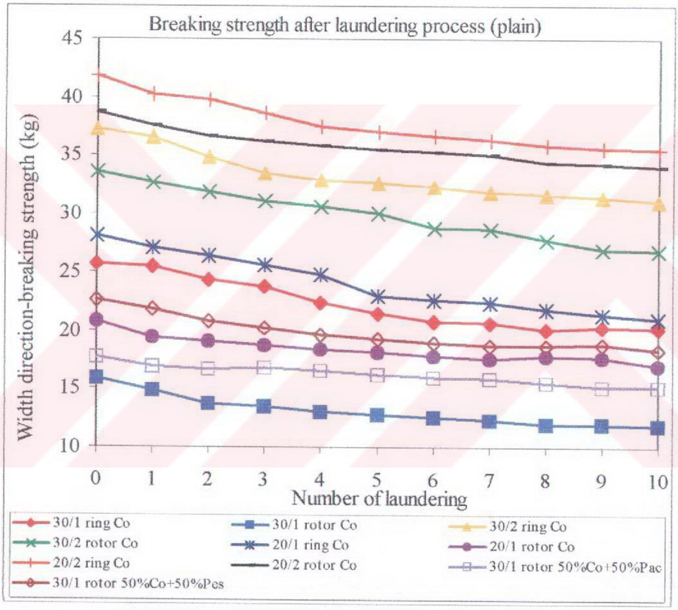


Figure 5.4 Widthwise direction breaking strength of plain knitted fabrics related to laundering process

First of all the lengthwise breaking strength values of plain fabrics are also investigated with respect to yarn ply and yarn count. As seen on graphics lengthwise breaking strength values are higher than widthwise breaking strength values are observed. The test results are given below after ten subsequent laundering and drying process;

i) fabric made of Ne 20/2 ring yarn 100% Co. =42.6 kg
ii) fabric made of Ne 20/1 ring yarn 100% Co. =28.3 kg
iii) fabric made of Ne 30/2 ring yarn 100% Co. =34.6 kg
iv) fabric made of Ne 30/1 ring yarn 100% Co. =24.2 kg

Calculations indicate the reducing the yarn count from Ne 30 to Ne 20 may improve the breaking strength of fabrics approximately 15%. The fabrics produced by plied yarns breaking strength values are 32% higher than the fabric produced by single yarns.

Having same properties but different fiber blend ratios, are tested to examine the effect of fiber blending on the breaking strength of fabrics. The breaking strength values of the following fabrics are given below;

i) fabric made of Ne 30/1 rotor yarn 100% Co. = 15.8 kg
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =20.1 kg
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =20.6 kg

Blending of cotton with polyester or acrylic by 50% may improve the breaking strength as much as 22%.

Yarn production methods have also some effects on the breaking strength values. Different fabrics made of ring and rotor spun yarn are compared to see the effects of yarn production methods. The breaking strength values of the following fabrics are given below.

i) fabric made of Ne 30/1 ring yarn 100% Co. =24.2 kg
ii) fabric made of Ne 30/1 rotor yarn 100% Co. =15.8 kg

The above results clearly show that the fabrics produced from ring yarns have 35% higher breaking strength values than the fabrics produced from rotor yarns.

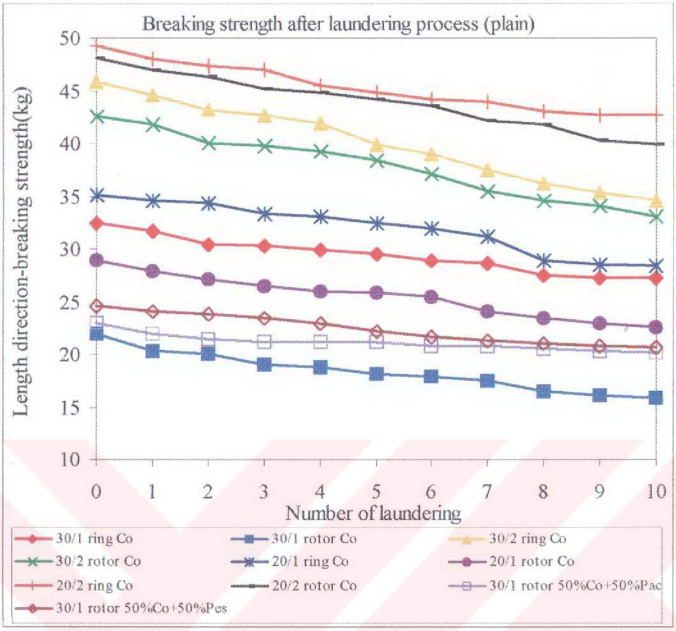


Figure 5.5 Lengthwise direction breaking strength of plain knitted fabrics related to laundering process

5.3.1.3. Change in breaking elongation

In addition to investigation of breaking strength, we also observed breaking elongation of plain knitted fabrics. Widthwise and lengthwise direction breaking elongation of plain fabrics are given on Figure 5.6 and 5.7.

It is observed that widthwise direction breaking elongation of cotton knitted fabrics are changed in the ratio 20% between first and last laundering process. In addition to this, fabrics which are produced from Ne 30/1 50/50 cotton/polyester and Ne 30/1 50/50 cotton/acrylic have less breaking elongation then the fabrics produced from Ne 30/1 100% cotton yarn.

Widthwise direction breaking elongation test values are given below;

i) fabric made of Ne 20/2 ring yarn 100% Co. =160.5%
ii) fabric made of Ne 20/1 ring yarn 100% Co. =140.4%
iii) fabric made of Ne 30/2 ring yarn 100% Co. =134.5%
iv) fabric made of Ne 30/1 ring yarn 100% Co. =126.4%

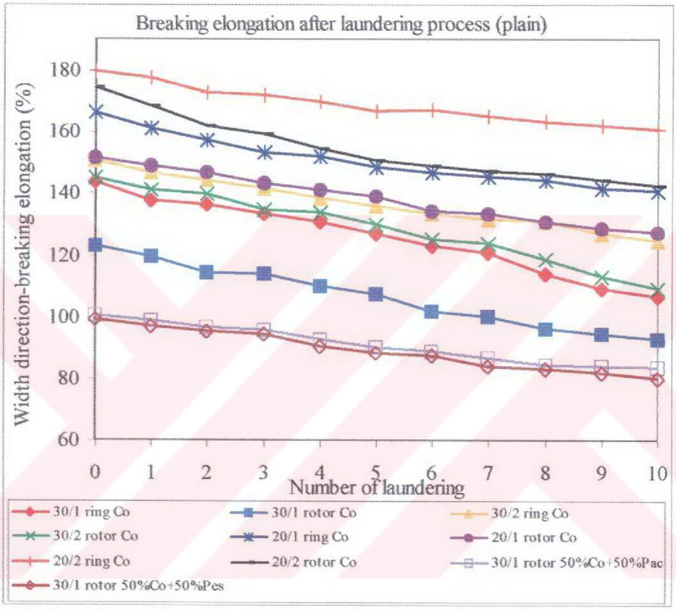


Figure 5.6 Widthwise direction breaking elongation of plain knitted fabrics related to laundering process

Having compared the spinning methods the fabric that made of ring yarn' breaking elongation values 12% higher than the fabric that made of rotor yarn.

i) fabric made of Ne 30/1 ring yarn 100% Co. =106.4%
ii) fabric made of Ne 30/1 rotor yarn 100% Co. =92.3%

In lengthwise direction plain fabrics which are produced from Ne 20/2 ring yarns have maximum breaking elongation value. In widthwise direction elongation graphic is similar to lengthwise elongation graphic. And also lengthwise direction breaking elongation values are lower than widthwise direction breaking elongation values for plain fabrics.

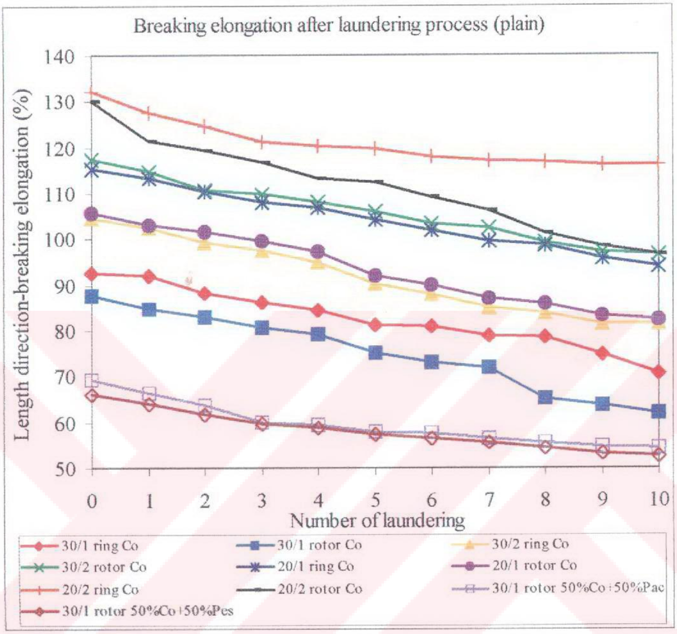


Figure 5.7 Lengthwise direction breaking elongation of plain knitted fabrics related to laundering process

5.3.2. Rib Knitted Fabrics

Rib fabrics are composed of loops formed in opposite directions, so when viewed from one side both back and face loops are apparent. All the loops of any one wale are of the same sort, either back or face. The name rib is derived from the ribs of animals, whose contours rib fabrics resemble. The simplest rib fabric is the 1x1. This is formed by alternating wales of back and face loops. Other constructions of rib are possible and are widely used, such as two wales of face loops alternating with two wales of face loops alternating with two wales of back loops to form 2x2 rib. On the same basis there are 3x3, 2x1, 3x2, etc.

5.3.2.1. Dimensional changes of rib knitted fabrics

Widthwise dimensional changes of rib fabrics which have different specification are given on Figure 5.8. As seen on the figure that each sample represents different shrinkage values.

In first test, rib fabrics, having same properties but different fiber blend ratios, are tested to examine the effect of fiber blending on the dimensional stability of fabrics. It is seen from the graphic the fabrics that are produced from polyester blends have less shrinkage than acrylic blend fabrics in the ratio of %0.8. The test results give the following shrinkage values for widthwise direction after ten subsequent laundering and drying processes:

i) fabric made of Ne 30/1 rotor yarn 100% Co. =23.2%
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =10.0%
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =9.2%

The shrinkage values of the fabrics show that fiber blend also plays an important role on the dimensional stability. Blending of cotton with polyester or acrylic by 50% may improve the dimensional stability as much as 58%.

The following fabric types are compared to investigate the effect of yarn counts on the dimensional stability;

i) fabric made of Ne 40/1 ring yarn 100% Co. =22.0%
ii) fabric made of Ne 30/1 ring yarn 100% Co. =21.2%
iii) fabric made of Ne 40/1 rotor yarn 100% Co. =24.4%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. =23.2%

Calculations indicate that reducing the yarn count from Ne 40 to Ne 30 may improve the dimensional stability of fabrics approximately 4.5%. So it is said that there is an inverse relationship between yarn count and shrinkage ratios. Rib fabrics which are made of Ne 40 and Ne 30 yarns' have higher widthwise and lengthwise shrinkage values than plain and lacoste fabrics.

One of the other investigated effect is the twist factor. The shrinkage values of the fabrics with twist factors are given below;

i) fabric made of Ne 40/1 ring yarn 100% Co. (900 turns/m) =22.0%
ii) fabric made of Ne 30/1 ring yarn 100% Co. (800 turns/m) =21.2%
iii) fabric made of Ne 40/1 rotor yarn 100% Co. (900 turns/m) =24.4%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. (800 turns/m) =23.2%

Yarn production methods have also some effects on the shrinkage ratio of fabrics as mentioned earlier. In widthwise, the shrinkage results of fabrics produced from ring and rotor spun yarns are given below;

i) fabric made of Ne 40/1 ring yarn 100% Co. =22.0%
ii) fabric made of Ne 40/1 rotor yarn 100% Co. =24.4%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =21.2%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. =23.2%

The above results clearly show that the fabrics produced from rotor spun yarns exhibit more shrinkage than the fabric produced from ring spun yarns.

Yarn ply is another important factor that affects the shrinkage ratio of the fabrics. As seen in graphic shrinkage values of single yarn are higher than fabrics which made of plied yarn;

i) fabric made of Ne 40/1 ring yarn 100% Co. =22.0%
ii) fabric made of Ne 40/2 ring yarn 100% Co. =18.5%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =21.2%
iv) fabric made of Ne 30/2 ring yarn 100% Co. =16.8%
v) fabric made of Ne 40/1 rotor yarn 100% Co. =24.4%
vi) fabric made of Ne 40/2 rotor yarn 100% Co. =19.8%
vii) fabric made of Ne 30/1 rotor yarn 100% Co. =23.2%
viii) fabric made of Ne 30/2 rotor yarn 100% Co. =18.1%

The results show that the fabrics produced by single yarns have more shrinkage than the fabrics produced by plied yarns. The difference may change between 17%-20% depending on the fineness of the yarn and the production method.

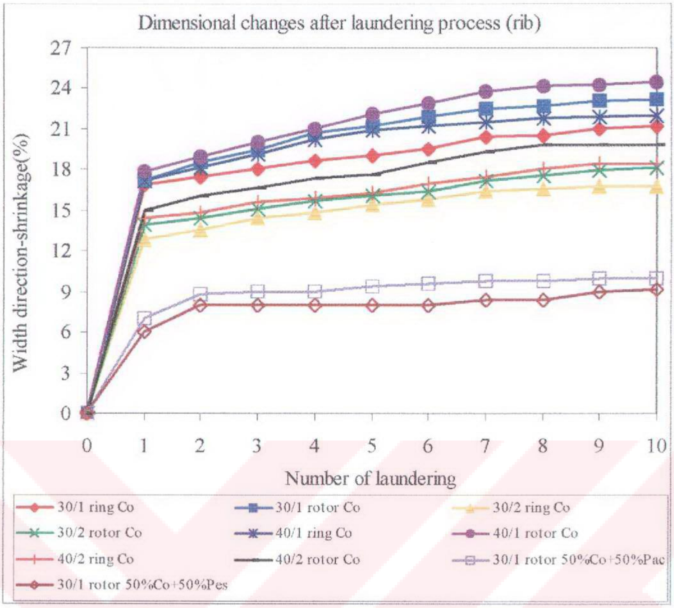


Figure 5.8 Widthwise direction dimensional changes of rib knitted fabrics related to laundering process

Lengthwise dimensional changes of rib fabrics are given on Figure 5.9. The test results give the following lengthwise direction shrinkage values after ten subsequent laundering and drying processes;

i) fabric made of Ne 30/1 rotor yarn 100% Co. =18.0%
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =11.5%
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =11.0%

The shrinkage values of the fabrics show that fiber blend has an important effect on the dimensional stability. Blending of cotton with polyester or acrylic by 50% may improve the dimensional stability as much as 37%.

The following fabrics are compared to investigate the effect of yarn counts on the dimensional stability;

i) fabric made of Ne 40/1 ring yarn 100% Co. =17.5%
ii) fabric made of Ne 30/1 ring yarn 100% Co. =17.1%
iii) fabric made of Ne 40/1 rotor yarn 100% Co. =19.0%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. =18.0%

Calculations indicate that reducing the yarn count from Ne 40 to Ne 30 may improve the dimensional stability of fabrics approximately 3.8%.

One of the other investigated effect is the twist factor. The shrinkage values of the fabrics with twist factors are given below.

i) fabric made of Ne 40/1 ring yarn 100% Co. (900 turns/m) =17.5%
ii) fabric made of Ne 30/1 ring yarn 100% Co. (800 turns/m) =17.1%
iii) fabric made of Ne 40/1 rotor yarn 100% Co.(900 turns/m) =19.0%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. (800 turns/m) =18.0%

Different fabrics made of ring and rotor spun yarns are compared to see the effects of yarn production methods. The fabrics types and their shrinkage results are given below;

i) fabric made of Ne 40/1 ring yarn 100% Co. =17.5%
ii) fabric made of Ne 40/1 rotor yarn 100% Co. =19.0%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =17.1%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. =18.0%

The above results clearly show that the fabrics produced from rotor spun yarns exhibit more shrinkage than the fabric produced from ring spun yarns.

The shrinkage values of the following fabrics are compared keeping the ply factor in mind. Single and double plied yarn tests results are given below;

i) fabric made of Ne 40/1 ring yarn 100% Co. =17.5%
ii) fabric made of Ne 40/2 ring yarn 100% Co. =15.2%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =17.1%
iv) fabric made of Ne 30/2 ring yarn 100% Co. =14.0%
v) fabric made of Ne 40/1 rotor yarn 100% Co. =19.0%
vi) fabric made of Ne 40/2 rotor yarn 100% Co. =16.4%

vii) fabric made of Ne 30/1 rotor yarn 100% Co. =18.0%

viii) fabric made of Ne 30/2 rotor yarn 100% Co. =15.4%

The results show that the fabrics produced by plied yarns have less shrinkage than the fabrics produced by single yarns. The difference may change between 13.5%-16% depending on the fineness of the yarn and the production methods.

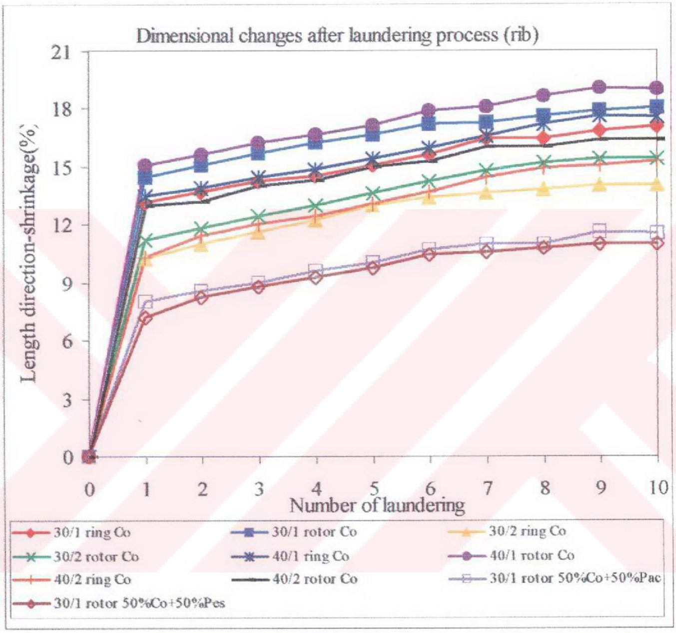


Figure 5.9 Lengthwise direction dimensional changes of rib knitted fabrics related to laundering process

Shrinkage curves in lengthwise direction has the same characteristics with the widthwise direction. But in lengthwise direction shrinkage values are 4-5% less than widthwise direction. Maximum shrinkage value is 19% and it belongs to fabrics that produced from Ne 40/1 rotor yarn same as in widthwise direction. Minimum shrinkage value belongs to Ne 30/2 cotton ring yarn with the ratio of 14%.

5.3.2.2. Change in breaking strength

Strength tests which are made of widthwise direction of fabric result excessive extensions and the extension values reach 200%, but no breakage can be observed until this value. Because of this reason just lengthwise breaking strength values are investigated in here.

Having observed fabric breaking strength and lengthwise direction breaking strength of rib fabrics are given on Figure 5.10.

Breaking strength of all fabrics have similar degree of decrease after laundering. Naturally fabric strength is related with fibre type, fibre length, yarn count, number of twist and spinning system so each fabrics have different strength values. Besides, the graphics are represented breaking strength is also given opportunity to analyze the strength changes of the fabric after laundering process.

First of all in rib fabrics breaking strength values are investigated with respect to yarn ply and yarn count;

i) fabric made of Ne 40/2 ring yarn 100% Co. =53.4 kg
ii) fabric made of Ne 40/1 ring yarn 100% Co. =30.1 kg
iii) fabric made of Ne 30/2 ring yarn 100% Co. =60.4 kg
iv) fabric made of Ne 30/1 ring yarn 100% Co. = 40 kg

The results clearly show that the fabrics that produced by plied yarns have 38% higher breaking strength than the fabrics that produced by single yarns. Calculations indicate that increasing the yarn count from Ne 40 to Ne 30 may improve breaking strength values approximately 10 kg.

Test values of rib knitted fabrics having the same properties but different fiber blend ratios are given below.

i) fabric made of Ne 30/1 rotor yarn 100% Co. =28.9 kg
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =44.5 kg
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =46.1 kg

Blending of cotton with polyester or acrylic by 50% may improve the breaking strength as much as 36%.

Having investigated breaking strength of the fabrics that made of ring or rotor yarn. It is observed that the fabrics which produced from Ne 40/1 ring yarn breaking strength value is 30.1 kg and for the fabrics that produced from rotor yarn breaking strength values of 19 kg.

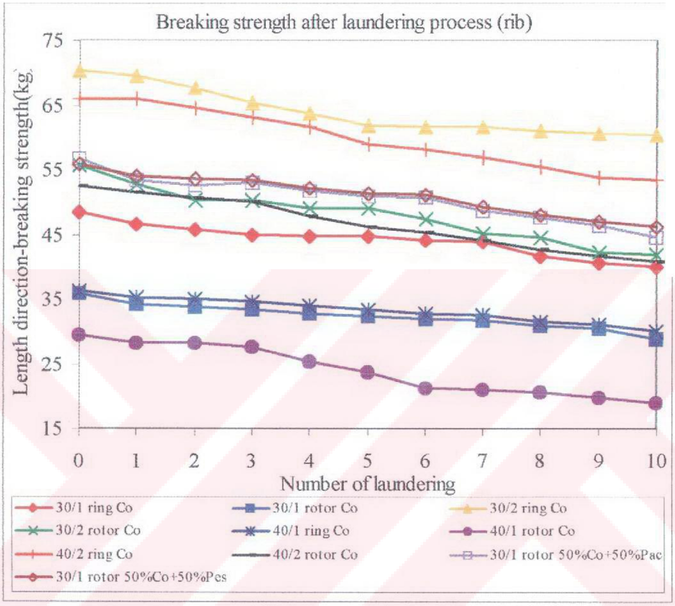


Figure 5.10 Lengthwise direction breaking strength of rib knitted fabrics related to laundering process

5.3.2.3. Change in breaking elongation

Breaking elongation of fabrics which is very important parameter and also represents how much dimensional change the fabric can allow. During the experimental studies, rib fabric which produced from different yarns in lengthwise direction breaking elongation values are given on Figure 5.11. All types of rib fabrics tested exhibit decrease of breaking elongation in lengthwise direction after each laundering process. And also breaking elongation values have parallel manner with breaking strength values.

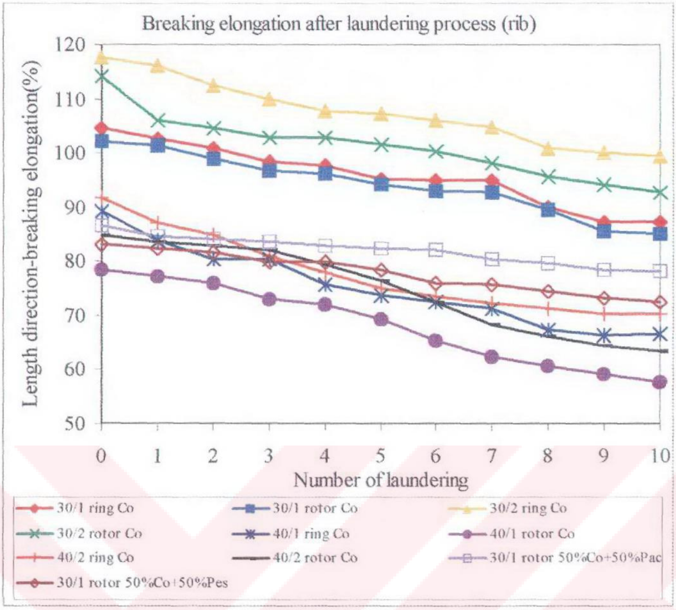


Figure 5.11 Lengthwise direction breaking elongation of rib knitted fabrics related to laundering process

As seen in graphics elongation values decrease in the ratio of 20% between the first and last laundering process. For the fabrics produced from blended yarns lengthwise direction breaking elongation results are close to each other. For these fabrics breaking strength results are quite high but elongation values are not good unexpectedly. Maximum breaking elongation value belongs to fabrics produced from Ne 30/2 ring yarn (99.2%) and minimum breaking elongation value belongs to fabrics that produced from Ne 40/1 rotor yarn (57.6%) after tenth laundering process.

Because of excessive extension in widthwise direction we can not perform the strength results of rib fabrics in widthwise direction.

5.3.3. Lacoste knitted fabrics

A fine cut fabric usually made from mercerized cotton or polyester/cotton blend yarn, and widely used for knit sport shirts. This is a jersey-type fabric which contains a specific pattern (honeycomb) of knit and tuck stitches. It is one of the derivatives of the plain knitted fabrics.

5.3.3.1. Dimensional changes of lacoste fabrics

Widthwise direction dimensional changes of the lacoste knitted fabrics are given on Figure 5.12. The test results give the following shrinkage values after ten subsequent laundering and drying processes to examine the effect of fiber blending on the dimensional stability of fabrics;

i) fabric made of Ne 30/1 rotor yarn 100% Co. =13.4%
ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =9.9%
iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =9.0%

The shrinkage values of the fabrics show that blending of cotton with polyester or acrylic by 50% may improve the dimensional stability as much as 30%.

The following fabrics are compared to investigate the effect of yarn counts on the dimensional stability;

i) fabric made of Ne 40/1 ring yarn 100% Co. =14.0%
ii) fabric made of Ne 30/1 ring yarn 100% Co. =12.0%
iii) fabric made of Ne 40/1 rotor yarn 100% Co. =15.1%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. =13.4%

Calculations indicate that reducing the yarn count from Ne 40 to Ne 30 may improve the dimensional stability of fabrics approximately 12.8%.

The shrinkage values of the fabrics with twist factors are given below;

i) fabric made of Ne 40/1 ring yarn 100% Co. (900 turns/m) =14.0%
ii) fabric made of Ne 30/1 ring yarn 100% Co. (800 turns/m) =12.0%
iii) fabric made of Ne 40/1 rotor yarn 100% Co. (900 turns/m) =15.1%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. (800 turns/m) =13.4%

The fabrics types and their shrinkage results are given below to see the effects of yarn production methods;

i) fabric made of Ne 40/1 ring yarn 100% Co. =14.0%
ii) fabric made of Ne 40/1 rotor yarn 100% Co. =15.1%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =12.0%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. =13.4%

The above results clearly show that the fabrics produced from rotor spun yarns exhibit more shrinkage than the fabric produced from ring spun yarns.

Yarn ply is another important factor that affects the shrinkage ratio of the fabrics. The first assumption is that the fabrics produced from plied yarns will exhibit similar results to that of fabrics produced by single yarns, since both yarns have same counts and same twist number. However, interestingly, the plied yarns cause less shrinkage with respect to the fabrics of single yarns. The shrinkage results of the following fabrics are compared. These results proves decreasing effect of yarn ply on dimensional stability;

i) fabric made of Ne 40/1 ring yarn 100% Co. =14.0%
ii) fabric made of Ne 40/2 ring yarn 100% Co. =12.5%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =12.0%
iv) fabric made of Ne 30/2 ring yarn 100% Co. =10.5%
v) fabric made of Ne 40/1 rotor yarn 100% Co. =15.1%
vi) fabric made of Ne 40/2 rotor yarn 100% Co. =13.1%
vii) fabric made of Ne 30/1 rotor yarn 100% Co. =13.4%
viii)fabric made of Ne 30/2 rotor yarn 100% Co. =11.6%

The results show that the fabrics produced by plied yarns have less shrinkage than the fabrics produced by single yarns. The difference may change between 12%-15% depending on the fineness of the yarn and the production method.

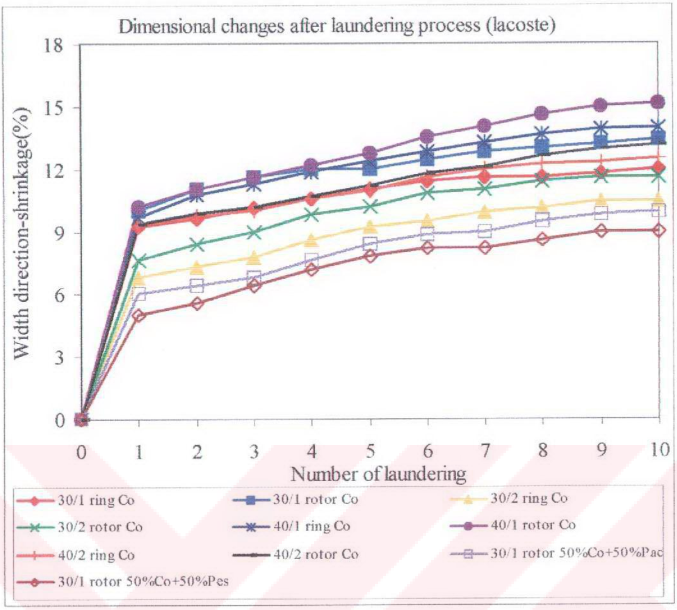


Figure 5.12 Widthwise direction dimensional changes of lacoste knitted fabrics related to laundering process

Lengthwise direction dimensional changes values lacoste fabrics after laundering process are given on Figure 5.13. The test results give the following shrinkage values after ten subsequent laundering and drying processes keeping the effect of fiber blending on the dimensional stability of lacoste fabrics;

i) fabric made of Ne 30/1 rotor yarn 100% Co. =16.6%

ii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pac. =11.8%

iii) fabric made of Ne 30/1 rotor yarn 50% Co+ 50% Pes. =11.4%

Blending of cotton with polyester or acrylic by 50% may improve the dimensional stability as much as 30%. It's clear from the results cotton determinates the dimensional stability of lacoste fabrics.

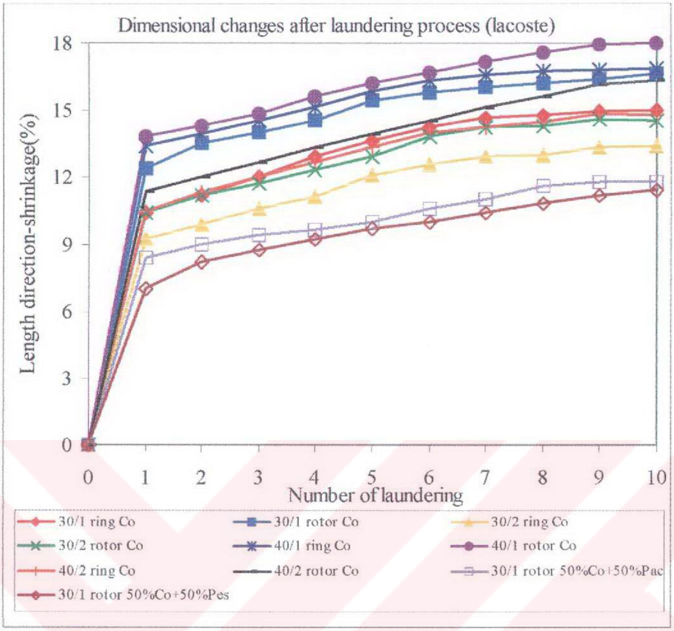


Figure 5.13 Lengthwise direction dimensional changes of lacoste knitted fabrics related to laundering process

The following fabrics are compared to investigate the effect of yarn counts on the dimensional stability;

i) fabric made of Ne 40/1 ring yarn 100% Co.	=16.9%
ii) fabric made of Ne 30/1 ring yarn 100% Co.	=15.0%
iii) fabric made of Ne 40/1 rotor yarn 100% Co.	=18.0%
iv) fabric made of Ne 30/1 rotor yarn 100% Co.	=16.6%

Calculations indicate that reducing the yarn count from Ne 40 to Ne 30 may improve the dimensional stability of fabrics approximately 9.5%. So it is said that there is an inverse relationship between yarn count and shrinkage ratios.

The shrinkage values of the fabrics with twist factors are given below;

i) fabric made of Ne 40/1 ring yarn 100% Co. (900 turns/m) =16.9%
ii) fabric made of Ne 30/1 ring yarn 100% Co. (800 turns/m) =15.0%
iii) fabric made of Ne 40/1 rotor yarn 100% Co.(900 turns/m) =18.0%
iv) fabric made of Ne 30/1 rotor yarn 100% Co.(800 turns/m) =16.6%

Different fabrics made of ring and rotor spun yarns are compared to see the effects of yarn production methods. The fabrics types and their shrinkage results are given below;

i) fabric made of Ne 40/1 ring yarn 100% Co. =16.9%
ii) fabric made of Ne 40/1 rotor yarn 100% Co. =18.0%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =15.0%
iv) fabric made of Ne 30/1 rotor yarn 100% Co. =16.6%

The above results clearly show that the fabrics produced from rotor spun yarns exhibit more shrinkage than the fabric produced from ring spun yarns.

Yarn ply is another important factor that affects the shrinkage ratio of the fabrics. The plied yarns cause less shrinkage with respect to the fabrics of single yarns. The shrinkage values of the following fabrics are compared.

i) fabric made of Ne 40/1 ring yarn 100% Co. =16.9%
ii) fabric made of Ne 40/2 ring yarn 100% Co. =14.8%
iii) fabric made of Ne 30/1 ring yarn 100% Co. =15.0%
iv) fabric made of Ne 30/2 ring yarn 100% Co. =13.4%
v) fabric made of Ne 40/1 rotor yarn 100% Co. =18.0%
vi) fabric made of Ne 40/2 rotor yarn 100% Co. =16.3%
vii) fabric made of Ne 30/1 rotor yarn 100% Co. =16.6%
viii) fabric made of Ne 30/2 rotor yarn 100% Co. =14.5%

The results show that the fabrics produced by plied yarns have less shrinkage than the fabrics produced by single yarns. The difference may change between 11%-12% depending on the fineness of the yarn and the production methods.

5.3.3.2. Change in breaking strength

Widthwise and lengthwise direction breaking strength values of lacoste fabrics are given on Figure 5.14 and 5.15. Widthwise and lengthwise direction breaking strength values of lacoste fabrics decreases one by one during laundering process.

First of all, according to the graphs widthwise breaking strength values are investigated with respect to the yarn ply and yarn count;

i) fabrics made of Ne 40/2 ring yarn 100% Co = 45.4 kg
ii) fabrics made of Ne 40/1 ring yarn 100% Co = 28.3 kg
iii) fabrics made of Ne 30/2 ring yarn 100% Co = 54.0 kg
iv) fabrics made of Ne 30/1 ring yarn 100% Co = 32.3 kg

For the fabrics have same yarn count and same specifications the fabrics produced by plied yarns breaking strength values are 39% higher than the fabrics produced by single ply yarns. As seen from the results the coarser the yarn count, results better the breaking strength;

i) fabrics made of Ne 30/1 rotor yarn 100% Co = 24.0 kg
ii) fabrics made of Ne 30/1 rotor yarn 50% Co + 50% Pes = 38.7 kg
iii) fabrics made of Ne 30/1 rotor yarn 50% Co + 50% Pac = 37.1 kg

The results clearly show that blending of cotton with polyester or acrylic by 50% may improve the breaking strength as much as 37%.

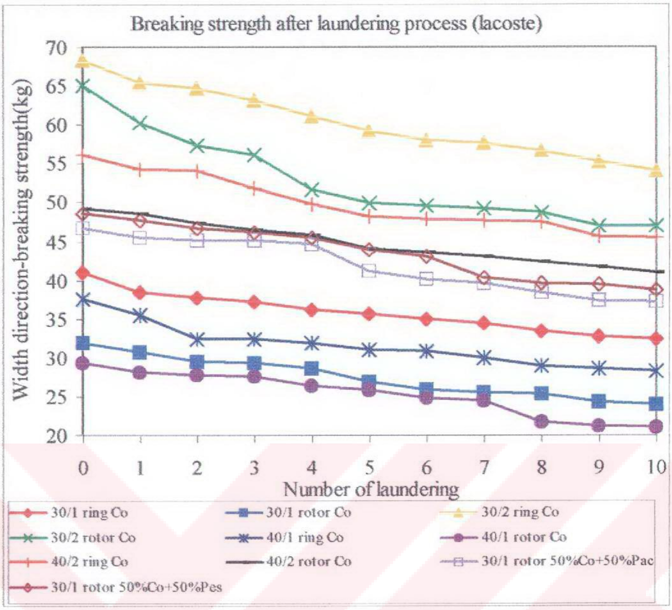


Figure 5.14 Widthwise direction breaking strength of lacoste knitted fabrics related to laundering process

i) fabrics made of Ne 40/1 ring yarn 100% Co =28.3 kg
ii) fabrics made of Ne 40/1 rotor yarn 100% Co =21.0 kg
iii) fabrics made of Ne 30/1 ring yarn 100% Co =32.3 kg
iv) fabrics made of Ne 30/1 rotor yarn 100% Co =24.0 kg

Having compared the spinning system each other, the fabrics that produced from ring yarn breaking strength values are approximately 25% higher than the fabrics that produced from rotor yarns.

After all lengthwise breaking strength values are also investigated with respect to the yarn ply and yarn count. For the lacoste fabrics widthwise breaking strength values are 50% higher in lengthwise direction;

i) fabrics made of Ne 40/2 ring yarn 100% Co. =21.0 kg

ii) fabrics made of Ne 40/1 ring yarn 100% Co. =10.1 kg
iii) fabrics made of Ne 30/2 ring yarn 100% Co. =31.4 kg
iv) fabrics made of Ne 30/1 ring yarn 100% Co. =13.1 kg

The fabrics produced by plied yarns breaking strength values are 55% higher than the fabrics produced by single ply yarns. The fabrics which made of Ne 30 ring yarn breaking strength values are 23% higher than the fabrics which made of Ne 40 ring yarn.

Having compared the fabrics, that made of 100% cotton and blending cotton with polyester or acrylic by 50% each other, are given below;

i) fabrics made of Ne 30/1 rotor yarn 100% Co. = 11.1 kg
ii) fabrics made of Ne 30/1 rotor yarn 50% Co + 50% Pes. = 19.8 kg
iii) fabrics made of Ne 30/1 rotor yarn 50% Co + 50% Pac. =18.0 kg

It is observed that, the fabrics which made of blending of cotton with polyester or acrylic by 50% breaking strength values 44% higher than the fabrics that made of 100% cotton;

i) fabrics made of Ne 40/2 ring yarn 100% Co. =21.0 kg
ii) fabrics made of Ne 40/1 ring yarn 100% Co. =10.1 kg

The fabrics that produced from ring yarn breaking strength values are approximately 35% higher than the fabrics that produced from rotor yarns for the same count and same yarn specifications after tenth laundering process.

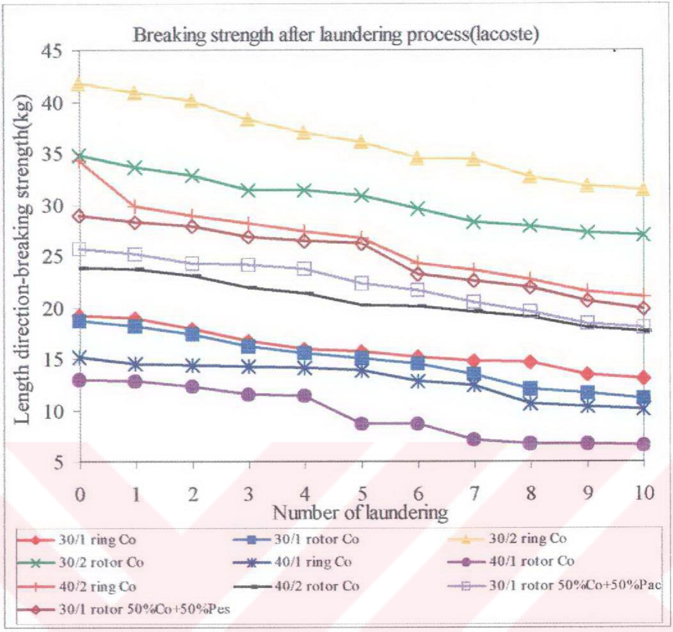


Figure 5.15 Lengthwise direction breaking strength of lacoste knitted fabrics related to laundering process

5.3.3.3. Change in breaking elongation

Widthwise direction breaking elongation of fabrics specimens are given on Figure 5.16. Having investigated widthwise direction breaking elongation of fabrics showed that fabrics which made of Ne 30/2 cotton ring yarns have the maximum breaking elongation and the value is 128.4% than it is followed by Ne 30/2 cotton rotor yarn which has 116.9% breaking elongation value after tenth laundering and drying process.

Fabrics which made of Ne 30/1 100%cotton rotor yarns breaking elongation value is 10% less than the fabrics which made of blending of cotton with polyester or acrylic by 50%;

i) fabrics made of Ne 30/1 rotor yarn 100% Co. =102.4%

ii) fabrics made of Ne 30/1 rotor yarn 50% Co + 50% Pes. =90%

iii) fabrics made of Ne 30/1 rotor yarn 50% Co + 50% Pac. =93.2%

The fabrics which made of ring yarns breaking elongation values are approximately 5% higher than the fabrics which made of rotor yarns.

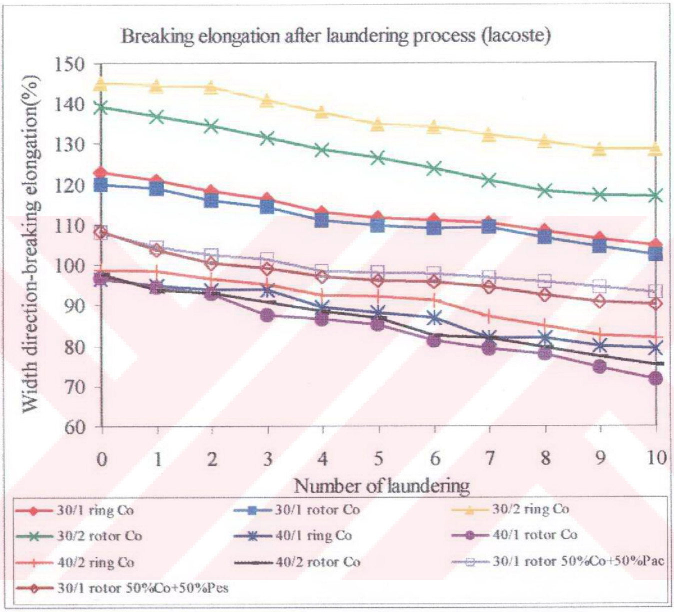


Figure 5.16 Widthwise direction breaking elongation of lacoste knitted fabrics related to laundering process

Lengthwise direction breaking elongation of fabrics specimens are given on Figure 5.17. Lengthwise direction breaking elongation values of fabrics have the same proportional values in comparison of widthwise breaking elongation values but, it is observed that elongation values in widthwise are 5-6% less than lengthwise direction values. Maximum widthwise and lengthwise breaking elongation value belongs to fabrics that made of 30/2 Ne ring yarn, minimum value belongs to fabrics that made of 40/1 Ne rotor yarn. After tenth laundering process fabrics that made of 30/2 Ne ring yarns' breaking elongation value is 111.6% and fabrics that made of 40/1 Ne rotor yarns' breaking elongation value is 55.8%.

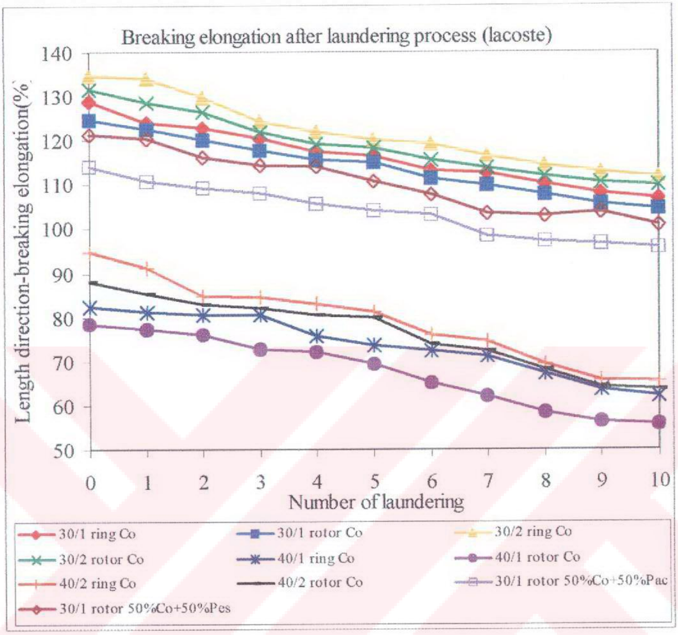


Figure 5.17 Lengthwise direction breaking elongation of lacoste knitted fabrics related to laundering process

5.4. Results and Discussion

In this section total shrinkage values for lengthwise and widthwise direction of sample fabrics are given by graphics. After completed last laundering process shrinkage values of plain fabrics are given in Figure 5.18. and 5.19.

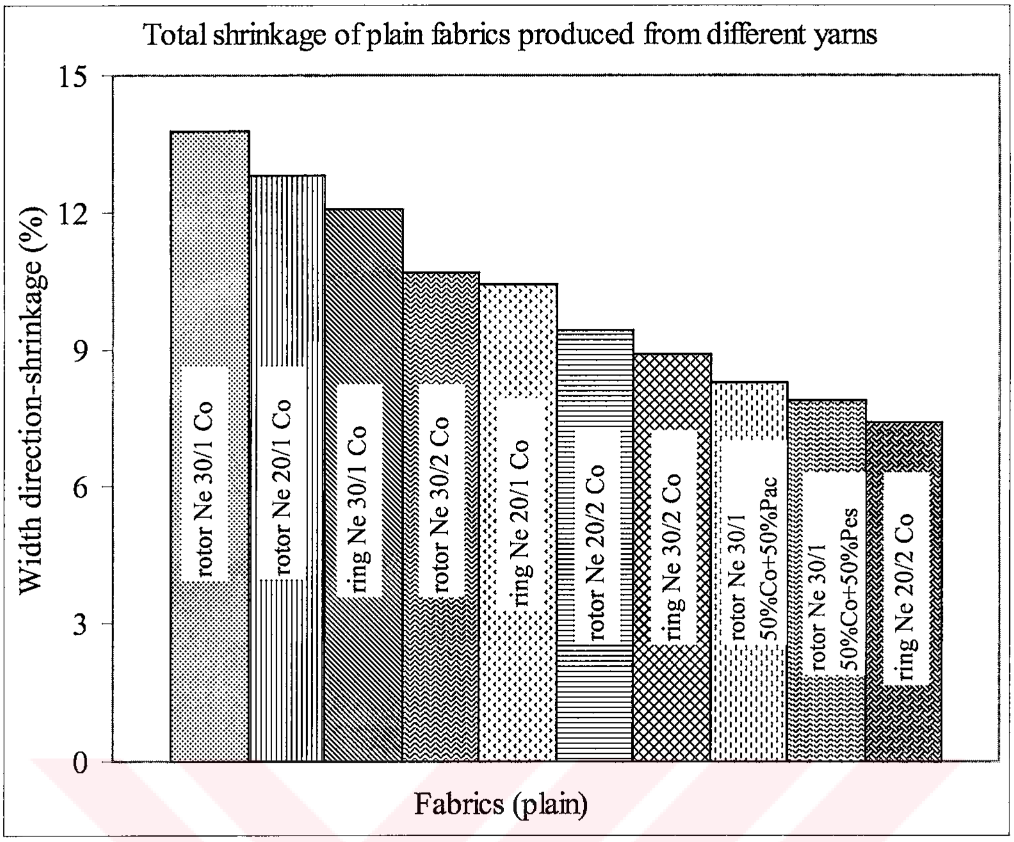


Figure 5.18 Total shrinkage of plain fabrics in widthwise direction

As seen in graphics eventhough fabric produced from Ne 30/1 rotor cotton yarn has 13.8% maximum shrinkage fabric produced from Ne 20/2 ring cotton yarn has 7.4% minimum shrinkage. The shrinkage values of other fabrics that have different qualifications are present in the region between the two mentioned extreme values. It is clear that from the graphics 5.18 and 5.19 increasing the yarn thickness, changing the production technology from rotor to ring, increasing the ply of the yarn and using synthetic blends provides a development for shrinkage behavior of knitted fabrics.

Fabrics produced from Ne 30/1 ring cotton yarn, Ne 20/1 ring cotton yarn, Ne 30/2 ring cotton yarn, Ne 20/2 ring cotton yarn exhibit 2-3% of development of shrinkage behavior in comparison to Ne 30/1 rotor cotton yarn, Ne 20/1 rotor cotton yarn, Ne 30/2 rotor cotton yarn and Ne 20/2 rotor cotton yarn respectively. It's proved that this improvement of lengthwise and widthwise direction shrinkage behavior is caused because of production technology seen from three samples in the same way in Figure 5.18 and 5.19. It's clear from the Figure 5.18 that shrinkage result of Ne 30/1 ring cotton yarn is less than Ne 30/1 rotor cotton yarn and Ne 20/1 rotor cotton yarn. So it can be observed that production technology effects the width direction shrinkage behavior more positive than increasing the yarn thickness.

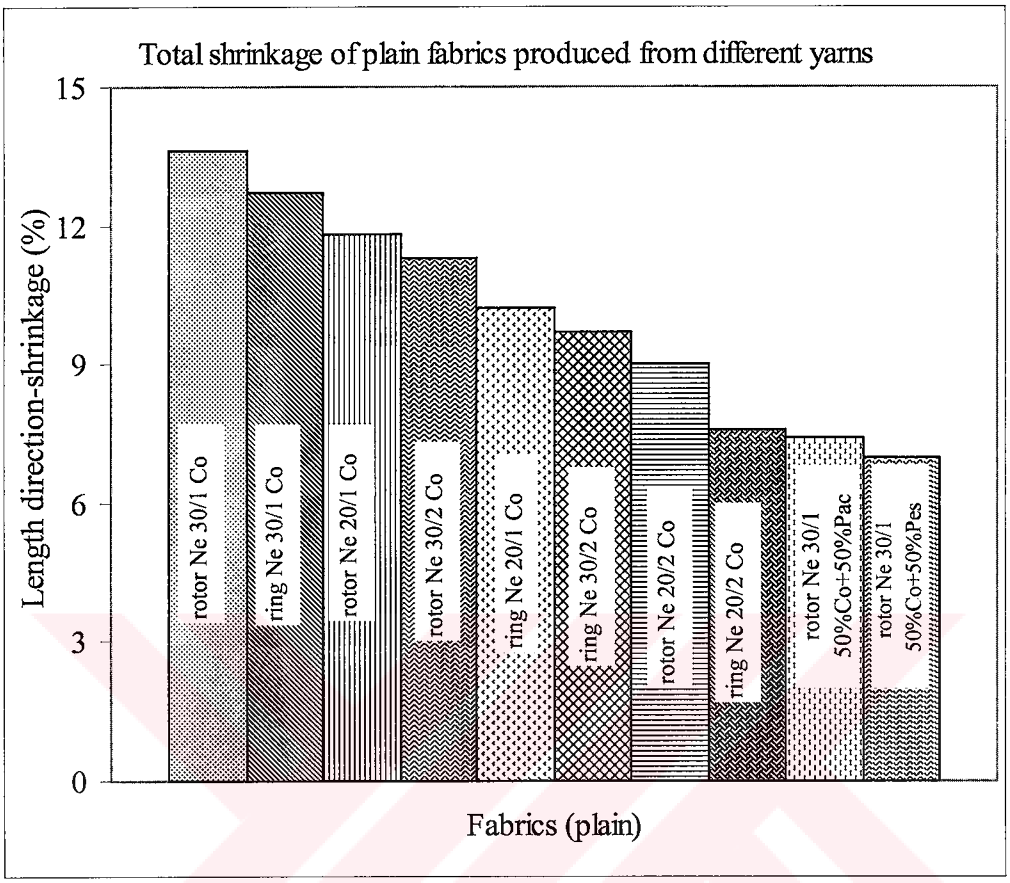


Figure 5.19 Total shrinkage of plain fabrics in lengthwise direction

From the view of yarn ply if Ne 30/1 rotor cotton yarn, Ne 20/1 rotor cotton yarn, Ne 30/1 ring cotton yarn, Ne 20/1 ring cotton yarn is compared with Ne 30/2 rotor cotton yarn, Ne 20/2 rotor cotton yarn, Ne 30/2 ring cotton yarn and Ne 20/2 ring cotton yarn respectively 3-4% improvement of shrinkage behavior is observed from Figure 5.18 and 5.19. This is a result of increasing the ply of the yarn.

Widthwise and lengthwise shrinkage values of rib fabrics are given in Figure 5.20 and Figure 5.21. From Figure 5.20 and 5.21, keeping the single and double plied yarns in mind, Ne 30/1 rotor cotton yarn, Ne 30/1 ring cotton yarn, Ne 30/2 ring cotton yarn and Ne 30/2 rotor cotton yarns have less shrinkage values than Ne 40/1 rotor cotton yarn, Ne 40/1 ring cotton yarn, Ne 40/2 ring cotton yarn, Ne 40/2 rotor cotton yarn respectively. It is seen that widthwise and lengthwise shrinkage values decreases by decreasing the yarn number.

Fabrics produced from cotton/synthetic blended yarns have less shrinkage values that is clear from Figure 5.20 and 5.21. If Ne 30/1 rotor cotton yarn compared with Ne 30/1 rotor 50/50 cotton/acrylic yarn 13.2% improvement of widthwise shrinkage and 6.5% improvement of lengthwise shrinkage is observed. And also Ne 30/1 rotor 50/50 cotton/polyester yarn exhibits the similar improvement with cotton/acrylic blend if compared with Ne 30/1 rotor cotton yarn.

It's seen from the figures maximum shrinkage values for both widthwise and lengthwise direction are obtained with rib fabrics in comparison to other knitted structures. Also it must be taken into consideration that there is an important distinct between legthwise and widthwise shrinkage values of rib fabric. This is a result of fabric structural behavior.

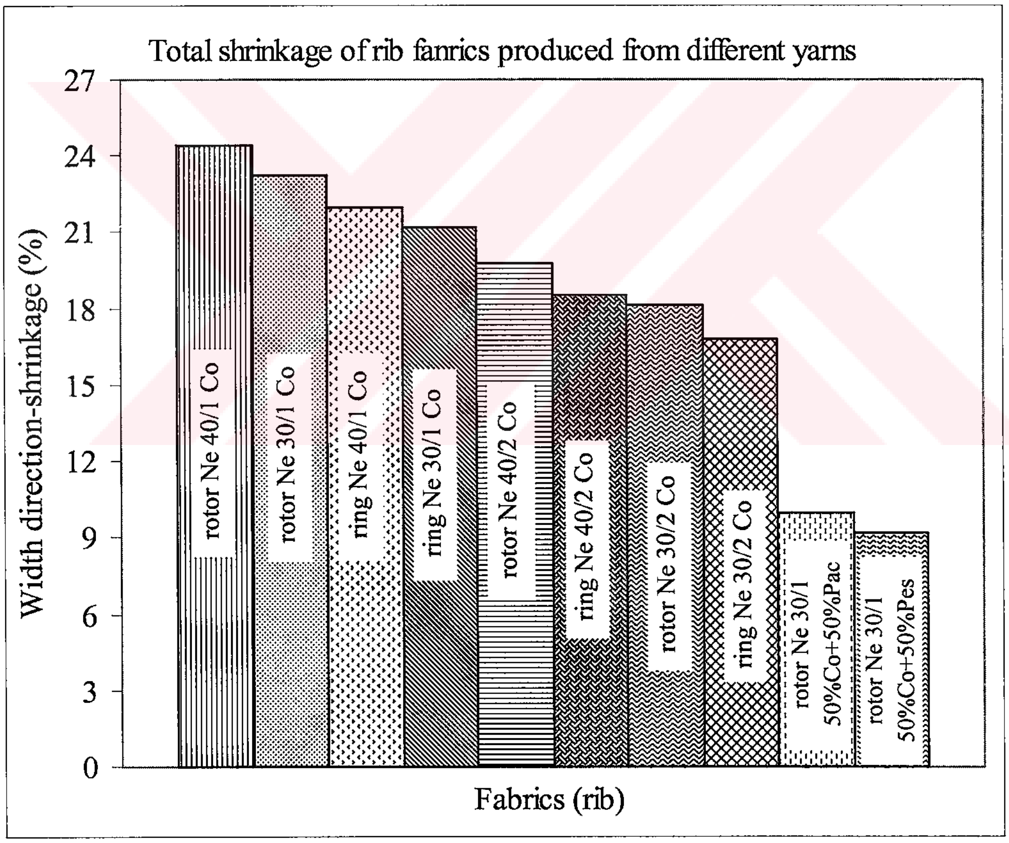


Figure 5.20 Total shrinkage of rib fabrics in widthwise direction

For both widthwise and lengthwise direction, fabrics produced from Ne 40/1 rotor cotton yarn has maximum shrinkage of 24.4% and 19%. Fabric produced from Ne 30/1 rotor 50/50 cotton/acrylic and Ne 30/1 rotor 50/50 cotton/polyester fabrics have shrinkage 11.5%, 11% shrinkage respectively for lengthwise and 10%, 9.2% shrinkage respectively for widthwise.

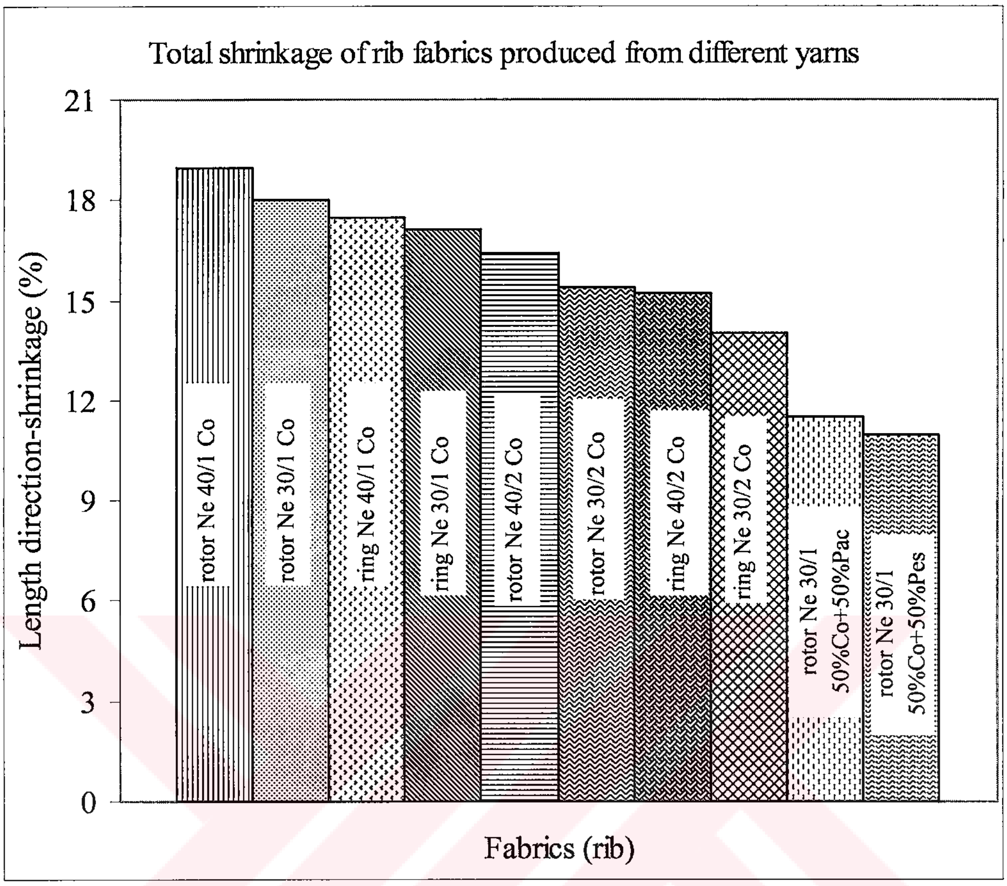


Figure 5.21 Total shrinkage of rib fabrics in lengthwise direction

For rib fabrics it is clear from the graphics 5.20 and 5.21 ring spinning technology, increasing yarn ply and yarn thickness and using synthetic blends influents the shrinkage values positively. But for rib fabrics spinning technology effects the shrinkage more than yarn ply in contrary to plain fabrics for lengthwise and widthwise.

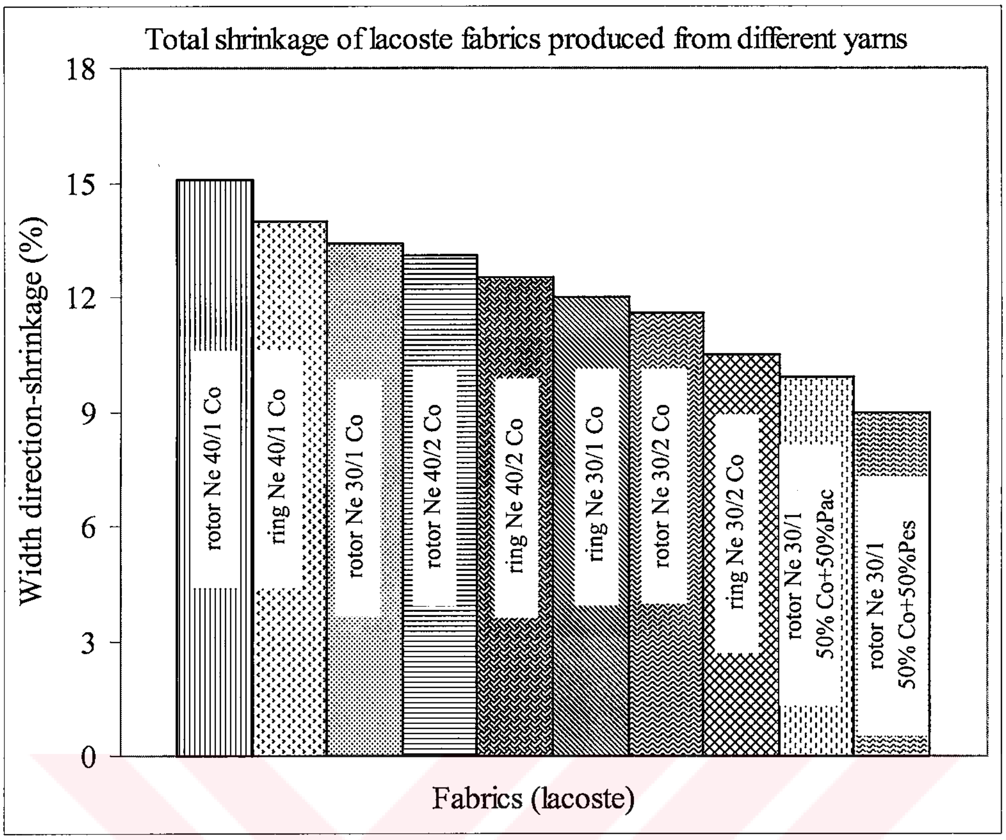


Figure 5.22 Total shrinkage of lacoste fabrics in widthwise direction

Widthwise and lengthwise shrinkage values of lacoste fabrics are given in Figure 5.22 and 5.23. As same with plain and rib fabrics ring spinning technology, decreasing yarn number and using synthetic blends effects the shrinkage values positively.

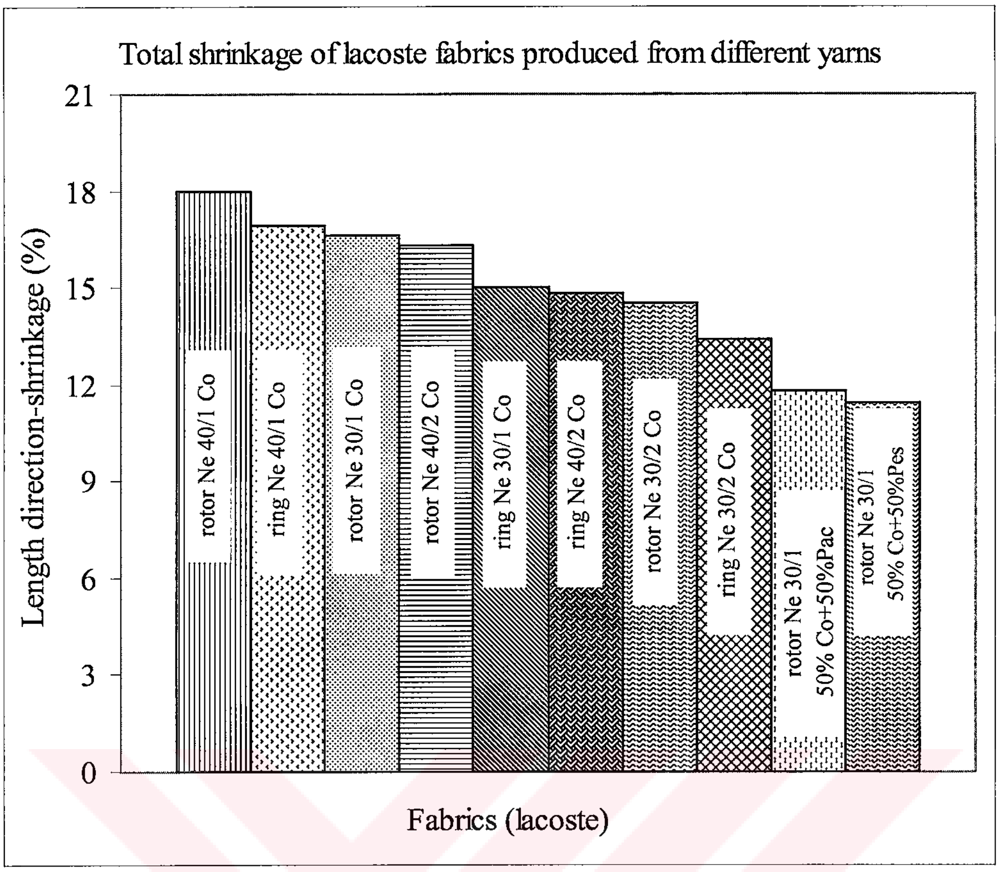


Figure 5.23 Total shrinkage of lacoste fabrics in lengthwise direction

Maximum shrinkage values for both widthwise and lengthwise, Ne 40/1 rotor cotton yarns have 15.1% and 18% respectively. Ne 30/1 rotor 50/50 cotton/polyester yarn have the minimum shrinkage values 9% for widthwise and 11.4% for lengthwise. And also Ne 30/1 rotor 50/50 cotton/acrylic yarn exhibits similar improvement with cotton/polyester blend if compared with Ne 30/1 rotor cotton yarn.

But polyester blend provides more improvement of shrinkage for both lengthwise and widthwise than acyrlic when blended with 50% to 50% ratios with cotton.

Table 5.3. Total shrinkage of fabrics produced from different yarns after tenth laundering process

Fabric structure	Yarn structure	Fiber structure	Dimensional Changes(%)	
			Widthwise shrinkage	Lengthwise shrinkage
Plain	rotor Ne 30/1	Cotton	13,8	13,6
	rotor Ne 30/2		10,7	11,3
	rotor Ne 20/1		12,8	11,8
	rotor Ne 20/2		9,4	9
	ring Ne 30/1		12,1	12,7
	ring Ne 30/2		8,9	9,7
	ring Ne 20/1		10,4	10,2
	ring Ne 20/2		7,4	7,6
Rib	rotor Ne 40/1	Cotton	24,4	19
	rotor Ne 40/2		19,8	16,4
	rotor Ne 30/1		23,2	18
	rotor Ne 30/2		18,1	15,4
	ring Ne 40/1		22,0	17,5
	ring Ne 40/2		18,5	15,2
	ring Ne 30/1		21,2	17,1
	ring Ne 30/2		16,8	14
Lacoste	rotor Ne 40/1	Cotton	15,1	18
	rotor Ne 40/2		13,1	16,3
	rotor Ne 30/1		13,4	16,6
	rotor Ne 30/2		11,6	14,5
	ring Ne 40/1		14,0	16,9
	ring Ne 40/2		12,5	14,8
	ring Ne 30/1		12,0	15
	ring Ne 30/2		10,5	13,4
Plain	rotor 30/1	50%Cotton+50%Acrylic	8,3	7,5
Rib			10	11,5
Lacoste			9,9	11,8
Plain	rotor 30/1	50%cotton+50%Polyester	7,9	7
Rib			9,2	11
Lacoste			9	11,4

As mentioned previously that many parameters effect the dimensional stability of fabrics, however, the contribution of each one will be explained here shortly. According to the tests applied to sample fabrics (these fabrics have different structure but their yarn and fiber parameters are same, i.e all yarns are produced from spinning, Ne 30/1 and made of cotton), the rib fabrics exhibits maximum shrinkage samples (21,2%) in widthwise and (17,1%) in lengthwise direction. Lacoste fabrics may have a shrinkage in lengthwise direction 15(%) as much as twice of shrinkage in widthwise direction (12%). On the other hand, plain fabric has similar shrinkage values in both direction and their numerical values are approximately 13,7% in both directions.

CHAPTER 6

CONCLUSION

The popularity of knitting has grown tremendously within recent years because of the increased versality techniques, the adaptability of the many new manmade fibers, and the growth in consumer demand for wrinkle-resistant, stretchable, snug-fitting fabrics, particularly in the greatly expanding areas of sportswear and other casual wearing apparel. The apparel knitting industry may be divided into four branches: knitted outwear, knitted yarn goods, knitted hosiery and knitted underwear. Today, the usage of knitted fabrics ranges from hosiery, underwear, sweaters, slacks, suits, and coats, to rugs and other home furnishings.

With the rising popularity of knitted fabrics, it brings some serious problem together. The difficulty of retaining the dimensional stability fabrics is one of the most important problems. Dimensional stability, is a resistance against physical changes of knitted fabrics. Shrinkage is a reduction in length (or width) of a fibre, yarn, fabric, or other textile, induced by conditioning, wetting, steaming, chemical treatment, wet processing as in laundering, dry heat or mechanical action. We called, increasing or reduction in dimensions of lengthwise or widthwise direction of fabrics as dimensional changes. Dimensional reduction is called shrinkage and dimensional increasing is called extension. Dimensional change is generally expressed by percentage. Many fabrics tend to lose its original dimension unless specific process is undertaken.

Depending on the dimensional type and amount of this type of loss, dimensional changes can turn back with refresh techniques but not all the time and not in the former condition. Generally whole shrinkage is not appeared after first laundering or dry cleaning process. There is still opportunity to shrink. For garments which are made of knitted fabrics; 2-3% shrinkage has minor importance values acceptable, many of the garments are traded. About 5-6% shrinkage is also known as acceptable by the consumer and, more than 10% shrinkage is an unusable in many knitted fabrics. The percentage of shrinkage's acceptable limits of knitted fabrics are higher than woven fabrics because of flexible knit structure. The factors that effects shrinkage of knitted fabrics are; water, heat, hot water, dry cleaning solvents and rinse.

Breaking strength and elongations of fabrics are the other important factors which are effected by washing, steaming and drying process, therefore these factors were also included in the study. Breaking strength is the maximum tensile force recorded in extending a test piece to breaking point. It's the force which is needed to break the fabric, under stress. Force which is applied parallel to the fabric plane and linearly break the yarns inside the fabric is called draft force. The tensile strength and the strength at break may be different if, the elongation continues and is accompanied by a drop in force resulting in tensile strength at break being lower than tensile strength. The tensile force recorded at the moment of rupture.

The deformation in the direction of load causes by a tensile force. Elongation is measured in units of length (e.g., millimeters). Elongation may be measured at any specified load or at the breaking load it is the extension percentage of a test specimen at breaking point.

The main aim of this work was to systematically investigate the effect of the principal washing and drying variables on the dimensional stability, elongation and breaking strength of knitted fabrics. In this study, the parameters are investigated for a series of plain, lacoste, rib, fabrics made from cotton, cotton/polyester and cotton/acrylic blended ring and rotor(open-end) spun yarns. These tests were made on with ISO standards and changes in the dimensions were measured right after each cycle.

The tests were performed on produced with different production techniques by applying ten laundering and drying process one after the other. Detailed analysis of many factors was made. These are;

fiber blend,
spinning system,
yarn twist (yarn count),
ply of yarn,
fabric structure (knit type).

The results show that the raw materials of yarns, yarn structure and fabric knit type take a large part to define the dimensional stability of these fabric types. Causes of major fabric changes were determined as the wash process variables (agitation level, detergent product, and drying method) and the different physical properties of the fiber types.

It is apparent from the results that fiber types in the yarns play an important role on the dimensional stability of fabrics. Because some fibers (i.e. cotton) have high absorbency ratios but and some of them not such as polyester and acrylic fibers. Absorbency is related with the swelling of fibers, and swelling causes to shorten of fibers. The experimental results show that blending of cotton with 50% acrylic or 50% of polyester improves considerably the dimensional stability of fabrics. The average reduction in shrinkage may be high as much as 50%.

Another important factor which affects dimensional changes with laundry process is spinning system of yarns. It is also apparent that the amount of shrinkage that occurs with open-end yarns is greater than with ring yarns. The shrinkage values of fabrics which are made of rotor yarns are approximately 10% higher than the fabrics produced from ring yarns. Furthermore, open-end spun yarns' fabrics tend to be weaker, which results in lower breaking strength than the fabrics of ring spun yarns.

Yarn twist is another factor to be considered for the shrinkage values of knitwear. Increasing twist number in a yarn means longer untwisted length (like sliver) of the yarn. It is obvious that longer yarns will exhibit higher amount of shrinkage. The experimental results show that the fabrics produced from higher amount of twisted yarns (800 turns/meter =Ne 30/1 yarns) display approximately 7% higher shrinkage with respect to the fabrics produced from low twisted yarns (650 turns/meter =Ne 20/1 yarns). A similar ratio can be obtain in the length difference of the high twisted yarn and low twisted yarn.

The fabrics produced from ply yarns is normally obtained feeding of two yarns (two 30/1 yarns or two 40/1 yarns) to each needle, and also their coarse and wale numbers are higher than that of the fabrics obtained from single yarns (see Table 5.1). That means these fabrics have much more denser structure and therefore may not allow shrinkage easily. This situation explains why the fabrics produced from plied yarns have less amount of shrinkage. The experimental results show that the shrinkage rations of fabrics of plied yarns may change between 10%-24% with respect to the fabrics of single yarns depending on the yarn fineness, yarn production methods and fabric structure.

Yarn structures also play an important role on the shrinkage values of fabrics since the length of the used up yarn for the same distance of knits are different at each structure and the since the density and thickness of these fabrics are also different. These factors are the basic factors which alter the shrinkage ratios of fabrics. The result show that the shrinkage values of plain fabrics (made of Ne 30/1rotor yarn) have similar shrinkage values of lacoste fabrics (made of Ne 30/1rotor yarn) approximately 13% in the width direction and 15% in the length directions, however, the rib structure exhibits shrinkage 23% in the width direction and 18% in the length direction.

Braking strength of fabrics depends on many parameters such as the structure of fabrics, yarn production methods, orientation of fibers in the yarn, fiber length, fiber fineness, trash content of the fibers and fiber blends. However, the following table rises up from a general comparison of the some fabrics from the point of view of breaking strength. The fabrics which are included in the comparison are made of;

a) fabric made of Ne30/1 ring yarn 100% Co.
b) fabric made of Ne30/1 rotor yarn 100% Co.
c) fabric made of Ne30/1 rotor yarn 50% Pes.+50% Co.
d) fabric made of Ne30/1 rotor yarn 50% Pac.+50% Co

The experimental results show the fabric produced from ring yarn has higher strength values than the fabrics made of rotor yarns. However, if polyester or acrylic is included in the content of fibers as much as 50%, then the breaking strength of these fabrics will be better than that of pure cotton.

The elongation values of the above fabrics (because these fabrics have many common parameters) show that the fabrics made of ring yarns have higher elongations than rotor yarn fabrics, but including of acrylics or polyester into the contents of fibers reduces the elongation values of the fabrics.

As a summary, dimensional stability is positively affected by using acrylic or polyester blended to cotton. Preferring the plied yarns to single and ring spun yarn to the rotor spun yarns may also improves the dimensional stability.

Recommendations

The further study on this subject may be structured as follows:

1) These tests may also be done on fabrics which are produced by the yarns of new spinning systems like friction, air-jet, and air-vortex.
2) It could be useful that during the experimental studies use of fabrics which are undertaken finishing process and compare the results.
3) It could be useful that use of different raw materials and properties like (silk, wool, viscos) and determine dimensional changes.
4) To determine the effect of laundering process, different temperature and different laundering time may be applied.

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