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INVESTIGATION OF SPIRALITY
ON SINGLE JERSEY FABRICS

M. Sc. THESIS
IN
TEXTILE ENGINEERING

BY

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Investigation of Spirality on Single Jersey Fabrics

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in
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Supervisor: Assist. Prof. Dr. Mehmet TOPALBEKİROĞLU

by

ZÜLEYHA DEĞİRMENCİ

August 2007

…to my mother

MERAL YURTYAPAN

and

…to my daughter

AYŞE YAREN DEĞİRMENCİ

ABSTRACT

INVESTIGATION OF SPIRALITY ON SINGLE JERSEY FABRICS

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Knitting is formed by series of loops, intermeshing in rows, each hanging from the last. Each loop is called as a stitch; a vertical row of stitches is a wale and a horizontal row of stitches is a course. Knitting has been the traditional method of producing sweaters, underwear, hosiery, baby blankets and sportswear. Knitting is divided into two major branches; namely warp and weft knitting. Weft knitting is a process in which one yarn or yarn set is carried out back and fronth under needles to form a knitted fabric. In knitted fabrics, the loop structure provides the fabric with outstanding elasticity and this factor generally causes 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. The wales are not perpendicular to courses as required but skew to the right or the left, forming an angle of spirality with the perpendicular.

The main goal of this study is to determine and investigate the factors that affect spirality in circular single jersey knitted fabrics produced from different yarn production technologies, yarn twist direction, the weight of fabric, application of elastic yarn and dyeing process. According to experimental study perform which have effects on spirality are found.

Key words: spirality, single jersey, yarn production technology, yarn twist, dyeing

ÖZET

SÜPREM KUMAŞLARDAKİ MAY DÖNMESİNİN İNCELENMESİ

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Örgü kumaşlar birbiriyle bağlantı yapan iplik halkalarından oluşmaktadır. İlmek olarak isimlendirilen her bir halka, düşeyde çubuk (may) ve yatayda sıra adı verilen örgü birimlerini oluşturur. Örme; kazak, iç giysilik, çorap ve bebek battaniyesi gibi çok kullanılan giysiliklerin yanında aktif olarak kullanılan spor kıyafetlerinde de oldukça popülerdir. Örgü işlemi temel olarak çözgü örmeciliği ve atkı örmeciliği olarak ikiye ayrılır. Atkı örmeciliği, bir ya da bir grup ipliğin örgü kumaşı oluşturmak üzere iğnelerin altına taşınmasıyla oluşturulur. May dönmesi, yuvarlak örgü kumaşta may sırasının düşey eksenden kayarak spiral bir yol izlemesi ve bu şekilde kumaş yapısının kötüleşmesidir. May dönmesinin gözlendiği yuvarlak örgü kumaşlarda may sıraları olması gerektiği gibi çubuk sıralarına dik değildir ve sağa veya sola doğru kayarak düşeyle aralarında dönme açısı adı verilen bir açı meydana getirirler.

Bu çalışmanın asıl amacı yuvarlak örgü ile elde edilmiş süprem kumaşlardaki örgü dönmesine iplik üretim teknolojilerinin, iplik büküm yönünün, kumaş ağırlığının, elastik iplik eklenmesinin ve boyamanın nasıl etkilediğinin araştırılmasıdır. Yapılan testler sonucunda incelenen parametrelerin örgü dönmesi üzerinde etkili olduğu saptanmıştır.

Anahtar kelimeler: may dönmesi, süprem kumaş, iplik üretim teknolojisi, büküm, boyama

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INTRODUCTION

1.1 INTRODUCTION

Textile materials and ready made clothes are generally used for protecting from environmental conditions, making life easy, covering body, and for being different from other people. Classes of textiles basically include woven, knitted and non-woven fabrics. The popularity of knitting has grown tremendously within recent years because of the increased versatility on 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. All the people use knitted fabrics during their life. Today, the usage of knitted fabrics ranges from hosiery, underwear, sweaters, slacks, suits, and coats, to rugs and other home furnishings.

A knitted structure is produced by a knitting machine. The knitting machine is sometimes called as knitting frame, knitting loom, or hand knitting machine. Knitting is performed briefly as the following: interlooping consists of forming yarns into loops each of which is typically only released after a succeeding loop has been formed and intermeshed with it so that a secure ground loop structure is achieved. A loop is the minor element of a knitted structure. The loops are also held together by the yarn passing from one to next. Knitted structures are generally divided as “warp knitting” and “weft knitting”. Weft knitted fabrics are the most commonly used type. There are four main structure for weft knits; plain (single jersey), rib, interlock and purl. In our daily life, plain knitted structures are used frequently.

Single Jersey fabrics are generally used for knitting underwear clothes, t-shirts, sportswear, pajamas, blouses and etc. These fabrics are knitted on circular weft knitting machine. They are easy to knit, cheap and have lighter weight than the fabrics which are knitted by other methods; so most of the manufacturers prefer this technique to produce simple structures. On daily life these fabrics are frequently washed, so they must withstand laundering and perform good shape retention without distortion. However, today dimensional instability and distortion after laundering are perceived as undesirable manners by the consumers.

Spirality arises from twist stress in the constituent yarns of plain fabric, causing all loops to distort and throwing the fabric wales and courses into an angular relationship other than 90^o. If the fabric is retained as a tube, the spirality throws the vertical alignment of the fabric away so that the wales lie at an angle to the edges of the fabric and slowly spiral around the fabric show obvious distortion and are worthless.

If the fabric is slit along a wale line during the knitting process or immediately prior to finishing, the distortion still takes place but appears as a course distortion, with the courses laying at an angle to the cut edges of the fabric. Fabrics with this problem often appear in low cost underwear and tee shirts, angled courses appearing to the consumer to be much less of a fault than angled wales.

Plain knitted fabrics made from single cotton yarn are most prone to spirality, the degree being related to the number of twists/unit length in the yarn. Such yarn is said to be ‘twist lively’ and, unlike similarly constructed yarns produced from thermoplastic fibers, can not be heat set in yarn or fabric for to eliminate spirality.

Spirality is measured by the number of degrees of distortion that the fabric is away from a 90^o relationship of wale to course. Fabrics of around 10^o spirality are commonly processed, although acceptability varies with the quality, price bracket, and end use of the particular goods. The acceptance level in knitted fabrics is 5^o.

Resin treatment known as cross linking is sometimes used to reduce the degree of distortion due to spirality. The resin is applied to the fabric in aqueous solution and is set by passing the fabric once through a high temperature stenter. Besides eliminating some or all of the spirality, improved dimensional stability, appearance and handle are claimed for the process. Its main drawback is a general weakening of the cotton fabric.

Spirality is minimized by the use of doubled (two-fold) yarns, but this pushes up the price prohibitively in all but the most expensive garments.

Spirality does not occur in 1*1 rib and interlock fabrics, the loops formed in opposite directions canceling out the distortions.

Another mild form of spirality occurs in fabrics produced on multifeeder circular machines, because the number of courses knitted in one revolution of the machine distorts the wale/course relationship. For example, a 30 in diameter machine with 90 feeders of 20 gauge will knit approximately 3 in of fabric every revolution. This will produce, if the fabric is finished 90^o open width, 2^o of spirality. Usually open width finishing with the fabric passing through a stenter will correct this. Finishing the fabric in tubular form will not. [1]

1.2 LITERATURE SURVEY

Araujo and Smith (1989) investigated spirality in both dry and fully relaxed Jersey fabrics produced from a series of relaxed spun yarns. They investigated the effect of yarn treatment, yarn plying and yarn plaiting on snarl on spirality. They used 20 different yarns with different properties that most of them are 100% cotton, few of them are 95.5% cotton– 0.05% LMP (Low Melt Polyester) and one of them is 100 % acrylic. As a result of this study, they observed that untreated yarns exhibited high tendency to snarl and fabrics knitted from these yarns have higher spirality. And also yarn dyeing, yarn steaming, yarn sizing with PVA (Polyvinilalcohol), heat setting of yarn and addition of LMP reduce spirality. On the other hand, they indicated that yarn plying and yarn plaiting reduced the spirality. [2]

Araujo and Smith (1989) studied on the effect of yarn spinning technology on the spirality of jersey fabrics in the dry and fully relaxed states for % 100 cotton and 50/50 cotton /PES blend yarns. The 100 % cotton yarns showed a greater angle of spirality than the 50/50 blend in the fully relaxed state. For 100 % cotton, for both dry relaxed and fully relaxed state, the angle of spirality decreases as follows; friction > ring > rotor > air-jet. For 50/50 blend yarns, both the air-jet and the rotor spun yarns, which have the lowest twist multiples and tendency to snarl , have the lowest angles of spirality in both the dry relaxed and fully relaxed states [3].

Tao, Dhingra and Chan (1997), produced 56 sample fabrics using cotton 100% ring spun yarns to investigate the effect of yarn count, yarn twist, and fabric tightness on spirality. They selected 3 yarn counts, 5 twist factors and 4 levels of tightness factor. This study revealed that the yarn twist and fabric tightness are the most predominant factors contributing to fabric spirality. The experimental results also demonstrated the importance of relaxation treatment on fabric spirality. [4]

Tao, Lo and Lau (1997), investigated the effect of yarn count and twist multiplier as functions of yarn parameters and fabric tightness as a function of fabric parameters. For this aim, they produced 30 fabrics from 100% cotton yarn. From the experiments, they found that modifying rotor spun yarns effectively reduced yarn twist liveliness to a very low or zero level. It was confirmed that the modified rotor yarn would greatly reduce fabric spirality for all cases studied. By the same way, fabrics made from the coarse yarns had higher levels of spirality than those from the finer yarns. [5]

Higgins et al (2003), investigated the effect of different tumble drying temperatures on shrinkage, skewness and spirality properties of 100% cotton plain, interlock and lacoste fabrics. They applied three drying conditions to fabrics; tumble drying at 65-57ºC, tumble drying 22ºC and flat drying at 65-57ºC. They observed the lowest spirality values for plain and lacoste fabrics at 65-57ºC tumble drying and 65-57ºC flat drying processes. On the other hand for interlock fabrics the spirality value is lowest for both 22ºC and 65-57ºC tumble drying processes. [6]

Chen et al (2003), investigated the relationship between the spirality of plain wool knits and production factors as twist coefficient, loop length, fiber diameter and tightness factor. They found that balanced twist factors for both ply and single yarns effect the fabric spirality. They also indicated that tightness factor have no significant effect on spirality while increasing loop length and fiber diameter cause higher spirality. [7]

Marmaralı (2003) made a research on dimensional and physical properties of cotton and cotton/spandex single jersey fabrics. In this research three different types tightness and two different types of cotton/spandex fabrics are used. At the end of this research it is found that the spirality is greater in loose fabrics and in non-spandex fabrics. Along with the fact that the spirality values of cotton/spandex fabrics are lower than 5º as an acceptable level, cotton/spandex fabrics which have spandex in every course have considerably lower spirality values than fabrics have spandex in alternating courses [8].

Marmaralı (2003) studied on the spirality of single jersey fabrics knitted with two plied cotton yarns. In this study different yarn twist and plying twist values are selected for 20 samples. This study showed that increasing the twist coefficient of single yarns increases spirality. In addition to this , the twist coefficient of folded yarns at S direction results in the lowest spirality. [9]

1.3 PURPOSE OF THESIS

The aim of this study is to investigate the causes and offer solutions of spirality on weft knitted single jersey fabrics which are 100 % cotton, Ne 30/1. The effect of yarn spinning technologies, machine parameters, lycra and dyeing on spirality will be examined. The fabric properties of sample fabric are given below;

1) Effect of yarn production technologies.

2) Effect of yarn twist direction.

3) Effect of fabric weight.

4) Effect of elastomer.

5) Effect of fabric dyeing.

Systematically the effect of the principal washing and drying variables on spirality are investigated. The fabrics are subjected to laundering followed by tumble drying. Spirality is measured after drying both gray and dyed fabrics.

1.4 STRUCTURE OF THESIS

Chapter 2 includes the information about knitting technology, the history of knitting, the difference between weaving and knitting; and between weft and warp knitting methods, basic knitted structures and their properties (plain knitted fabrics, rib knitted fabrics, purl knitted fabrics, interlock knitted fabrics). Knitting needles which are used in circular knitting were also explained in this chapter.

In Chapter 3, spirality was described. The nature and the reasons of spirality were given. Some solution ways to minimize spirality and the limitations of these ways were explained. The detailed information about testing method of spirality was given.

Chapter 4 was about the experimental studies. Fabric properties, standards, specimen preparing, test procedures were presented. The testing data was investigated, graphs of variables were drawn, and the results were assessed according to ANOVA by using SPSS 11.5 statistical software package. Finally Tukey Tables were examined according to the results.

In chapter 5 the conclusion about results and the recommendations to further studies were given.

CHAPTER 2

2.1 HISTORY OF KNITTING

Hand knitting, which is today once again a very popular and useful leisure activity, led the way to mechanical stitch formation. It is known that in Italy tight fitting leg wear from knitted fabrics existed as early as in the middle of the l3th century. The kind of stitch formation has been remained unchanged over several centuries. The pins were made out of smooth metal pieces, which were transformed into knitting needles and sharpened. The flexible fast-knitting needle for hand knitting is an invention of our century.

In Germany handicraft units were gathered into organized craft guilds and trade groups in the l5th century; they dealt with the production of stockings and gloves. A skilled hand-knitter produced 120-150 stitches per minute. In comparison, a modern high-speed circular knitting machine makes about 20 million stitches per minute.

1589: William Lee, the inventor of the mechanical stitch formation technique. A genial invention crowned his years of efforts: the hand knitting frame. By the time he produced the first mechanically-made stocking on this machine he had used up all his savings. But he had developed the basic principles of mechanical stitch formation, which are still valid today. The frame as seen in Figure 2.1, equipped with hook-shaped needles, was able to simultaneously produce 16 stitches in the same time needed by a skilled hand-knitter for just one stitch. Lee achieved this by kinking the required length of yarn for each stitch around the needle shaft one after the other into loops; this process is called couriering. In the second stage all the previous stitches were drawn over the new loops and thus a new row of stitches was produced.

By comparing first circular knitting machines (Figure 2.2) with modern circular knitting machines; technology will be determined by increase in performance, reductions in setting-up times and flexible utilization. The technical designer will have to deal with this challenge now and in the future [10].

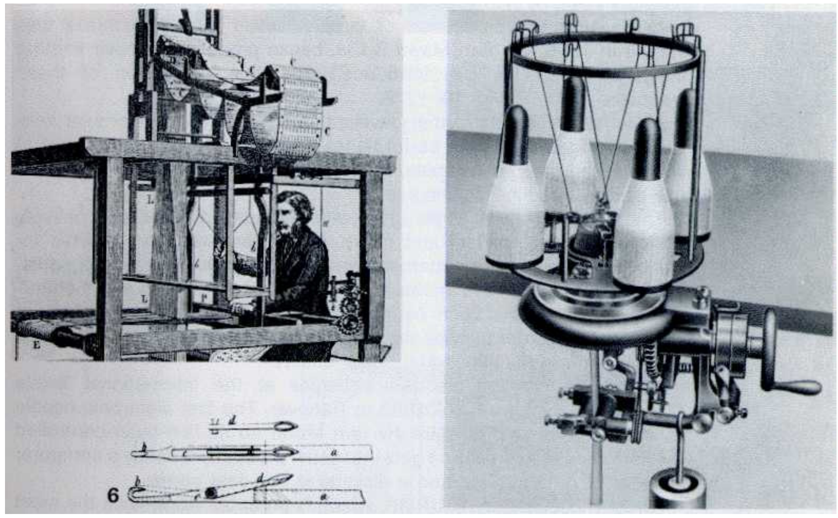


Figure 2.1 The invention of Lee

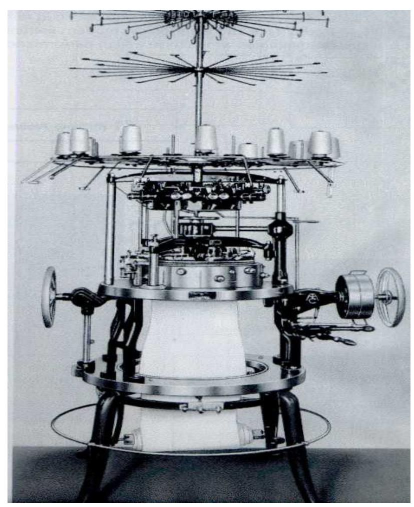


Figure 2.2 First circular knitting machine

2.2 THE PRINCIPLE OF KNITTING

Knitting is the most common method of interlooping of manufacturing textile structures. Knitting technology comprises all processes that are required to produce knitted fabrics [11]. Knitting is formed by a series of loops, intermeshing in rows, each hanging from the last. Each loop is called as a stitch; a vertical row of stitches is a wale and a horizontal row of stitches is a course [12].

In knitting, the yarns are initially formed into loops, and then these loops are interconnected 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 [13].

Modern machine knitting is of two types, weft and warp, terms relating the direction from which yarn is fed to the needles:

In weft knitting; Yarn is fed to the needles from the side, and loops are formed across a course [12]. The constituent loop of weft knitting is of the general shape shown in Figure 2.3. It has length (L) i.e the length of the thread forming it from a to b. This is the most important dimension and in fact decides the area the loop covers and its width and height within a construction [14].

In warp knitting; yarn is fed to the needles from the end, a separate yarn feed for each needle, so loops are formed in the direction of wales. Loops can be related to one another and can be intermeshed with one another to form fabrics [12]. 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 (as seen in Figure 2.4) [15].

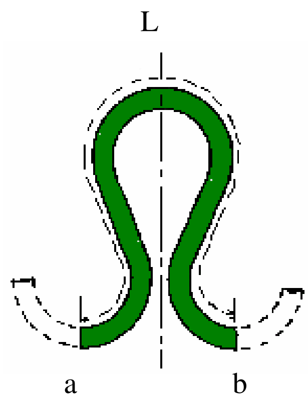
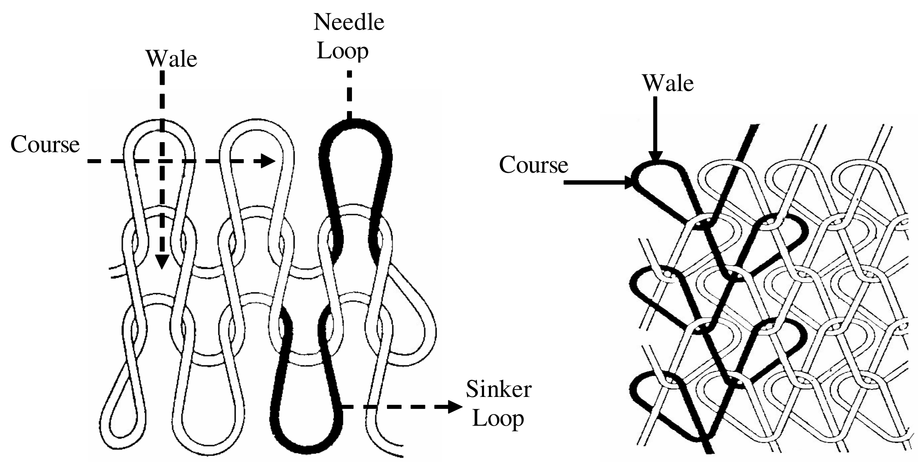


Figure 2.3 General shape of constituent loop of weft knitting



a) Weft knitting

b) Warp Knitting

Figure 2.4 Course and wale

2.3 COMPARISON OF KNITTING AND WEAVING

2.3.1 In Character

For a given quantity of yarn used, knits will;

- ❖ be lighter and more porous.
- ❖ be more easily distorted, leading to shrinking, or stretching and sagging.
- ❖ have comfort stretch.

The degree of comfort stretch varies with the type of yarn used, of course, but aside from that, it varies with the knit stitch, which in turn is governed by the kind of machine that produces into the type of needle used on that machine. So the character of knitted fabric depends on the type of machine used, much more than in weaving.

2.3.2 Using Area

The effects of the differing geometry of knits compared to wovens are seen in comfort, wear, and care.

Comfort; Knits are more comfortable in cold, still air, since the porous structure insulates better; it holds more air to prevent loss of body heat. However, in cold, windy weather, a closely woven fabric can give much more wind resistance. In wet conditions, knit will simply "strain the rain" without a water resistant layer, usually woven, behind it or on top. In hot, humid weather, a crisp woven fabric, especially made of spun yarns and in a basket plain weave, will allow the best air circulation over the skin to take perspiration away.

Wear; Knits, in general, are not as durable to hard wear as woven fabrics. Knits do have inherent wrinkle resistance, but can snagging or bagging in wear, especially single plain-stitch knits.

Care; Knits more easily clean than woven. Resistance to relaxation shrinkage is best with woven, or warp knits. Of the knits, warp knits and double knits generally show the best stability to care, such as machine washing and tumble drying.

2.3.3 Handling in Garment Construction

Pattern; The pattern must be suitable to the amount of stretch in the knit fabric used. Double knits and tricot have more of the stability of woven goods; single knits, especially plain stitch, or knits with stretch yarns require specially adapted patterns with less ease allowed.

Layout; Put as little tension as possible on knit fabric; allow it to lie and "relax" before cutting. Weft knits form "runs" one way. A silky interlock may run easily; if so, lay it so the run direction is up.

Stitching; Polyester thread is often used for some "give." Seams must have some elasticity; use zigzag or other stitch to give some stretch [12].

2.4 KNITTING ACTION

Knitting is a method of converting yarn into fabric by intermeshing loops, which are formed by the help of needles. The newly-fed yarn is converted into a new loop in each needle hook. The needle then draws the new loop head first through the old loop, which it has retained from the previous knitting cycle. The needles, at the same time, release, the old loops so they hang suspended by their heads from the feet of new loops whose heads are still held in the hooks of the needles.

2.4.1 Structural Elements in Knitted Fabrics

Loop; It is a basic unit consisting of a loop of yarn meshed at its base with previously formed basic units (stitches).

Stitch; The smallest dimensionally stable unit of all knitted fabrics is the stitch. It is consists of a yarn loop, which is held together by intermeshed with another stitch or other loops. (Figure 2.5)

a. Technical Face: This is the side of the stitch where the heads are above, and the feet are below the head of the preceding stitch. (Figure 2.6)

b. Technical Back: This is the side of the stitch where the heads are below, and the feet are above the head of the preceding stitch. (Figure 2.7)

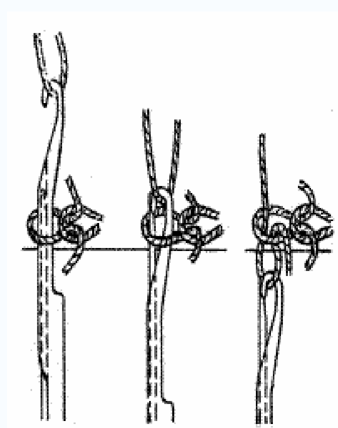


Figure 2.5 Stitch formation

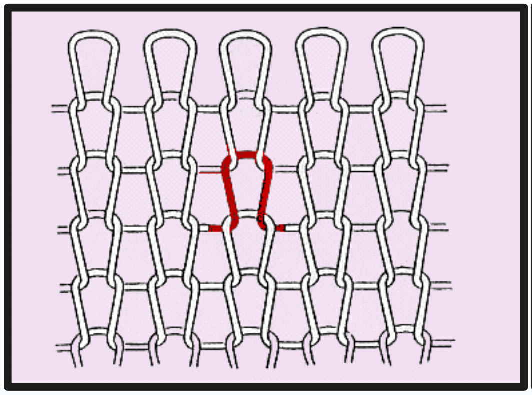


Figure 2.6 Technical face

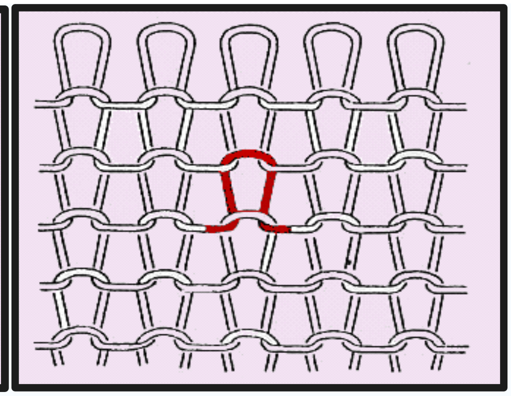


Figure 2.7 Technical back

2.4.2 Types of Needles

Three main types of needles are used in knitting machines, and they have a considerable effect on the character of the fabric produced; they are the latch and the beard or the spring beard needle. The formation of the stitches is different with these types of needles. In any machine knitting, the needle hook must be open to receive yarn that will form a new loop, but it must close to allow the needle carrying the yarn pass through the previous loop to form a chain [12].

Bearded Needle; 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 in Figure 2.8.

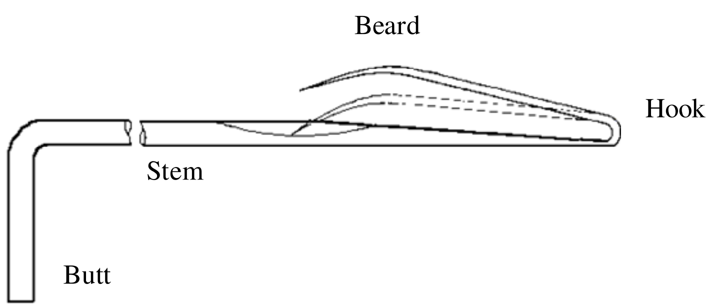


Figure 2.8 Bearded needle

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 [1].

Latch needles; Latch needle was invented by Matthew Townsend's in 1849 and since then it has challenged by the application of bearded needles in machine knitting (Figure 2.9). The latch needle is more expensive to manufacture than the bearded needle it is also 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 [14]. 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.

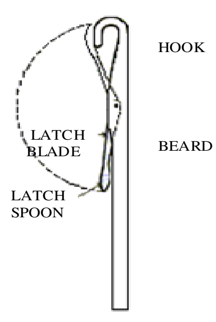


Figure 2.9 Latch needle

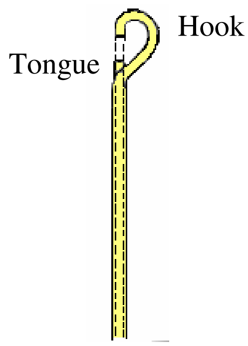


Figure 2.10 Compound needle

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 yarns [16]. This type of compound needle is particularly suited to the knitting of staple fibre and textured. (Figure 2.10)

2.5 CLASSIFICATION OF KNITTING

There are two main industrial categories of machine knitting; weft knitting and warp knitting as shown in Figure 2.11. 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 (Figure 2.12a), and a vertical set of yarns (warp) could be used to produce a warp knitted fabric (Figures 2.12b) [16]. Table 1.1 shows the comparison between warp knitting and weft knitting according to some criterias given above.

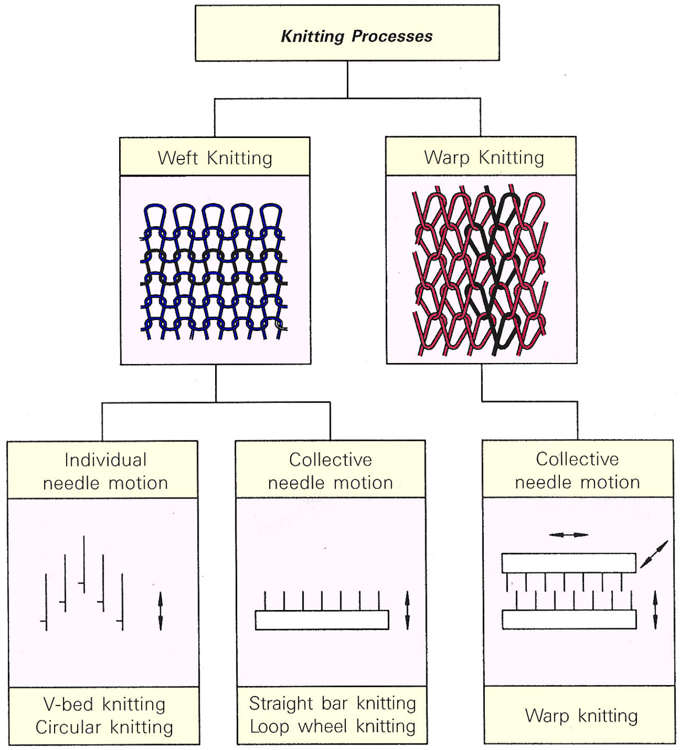
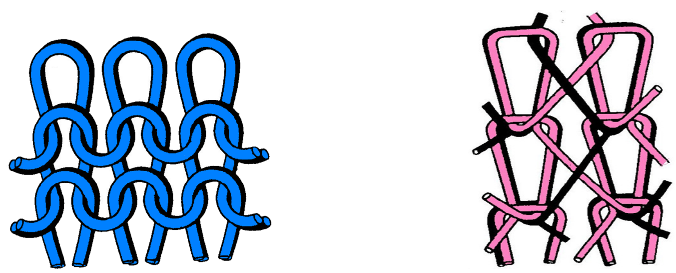


Figure 2.11 Classification of Knitting



(a) Weft knitting (b) Warp knitting

Figure 2.12 Types of the knitting structures

Table 1.1 Comparison between warp knitting and weft knitting according to given criterias [17]

Criterias	**Weft Knitting**	**Warp Knitting**
The direction of feeding	The direction of yarn is through widthwise of the fabric and a yarn passes over all needles	Each yarn makes loop goes in a zigzag form through the lengthwise of fabric.
Number of yarn	One yarn is enough	The number of warp yarns is equal least to the number of needles
Structure of loop	Loops are in open form	Loops are both open and close form
Structure of fabric	Voluminous, softer and draple	Dimensionally stable
Elasticity	Lenghtwise stability is lower but elasticity through lengthwise and widthwise is higher	Dimensional stability of warp yarns is generally close to weaving. Elasticity is lower.
Yarn snagging	Resistance to snagging is lower	Resistance to snagging is higher
Unravelability	Easy to unravel	Generally impossible to unravel through to the lengthwise and the widthwise
Pattern	Changing pattern is easy	Changing the pattern takes a long time
Humidity Absorption	The structure of is open and voluminous so absorption is higher.	The structure is tighter so absorption is lower

2.5.1 Warp Knitting

Warp knitting is accomplished by knitting loops along the length of the fabric, a series of closed loops are knitted in the lengthwise direction, as shown in Figure 2.12b. There are two major classes of warp knitting machines: tricot and Raschel. The tricot machine makes light weight fabrics and is frequently used in women's items such as lingerie, swimwear, and eveningwear. Coarser yarns are generally used for Raschel knitting in which the resulting knit fabric resembles hand crocheted fabrics,

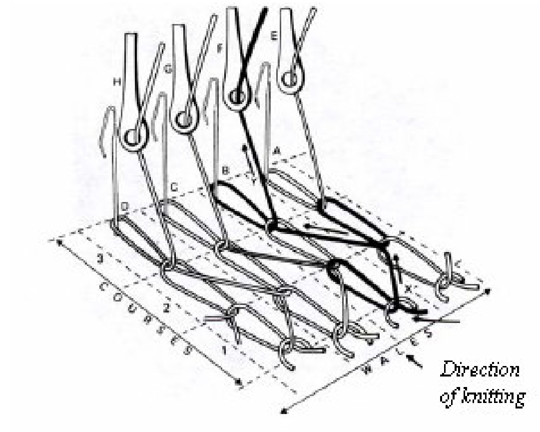


Figure 2.13 Length-wise knitting direction [1]

lace fabrics, and nettings commonly used for net curtains, table coverings, upholstery, and automobile interiors [1].

One distinguishing characteristic that sets warp knitting machines apart from weft machines is that the yarn source derives from beams instead of yarn packages (Figure 2.13). Weft knitting technology, rather than warp technology, will be the focus of the research. [1].

A bar guiding the yarns to the needles can move from one side to another, or to the front or back of the needle, so that the loops can be interlocked in a zigzag pattern. Very wide (over 400 cm, nearly 170 inch), flat fabric can be produced by warp knitting, at speeds in the order of 1,000 courses per minute, giving almost 3 m^2/min. The two main machine types are tricot and Raschel.

Tricot; Tricot is a machine with one needle bar and one to three guide bars. The spring beard needle, accepting mainly filament yarns, has limited the depth of texture that can be achieved in tricot fabrics; some fine spun tricot, produced on machines with hybrid needles, was introduced many years ago, but does not seem to have taken hold in the marketplace.

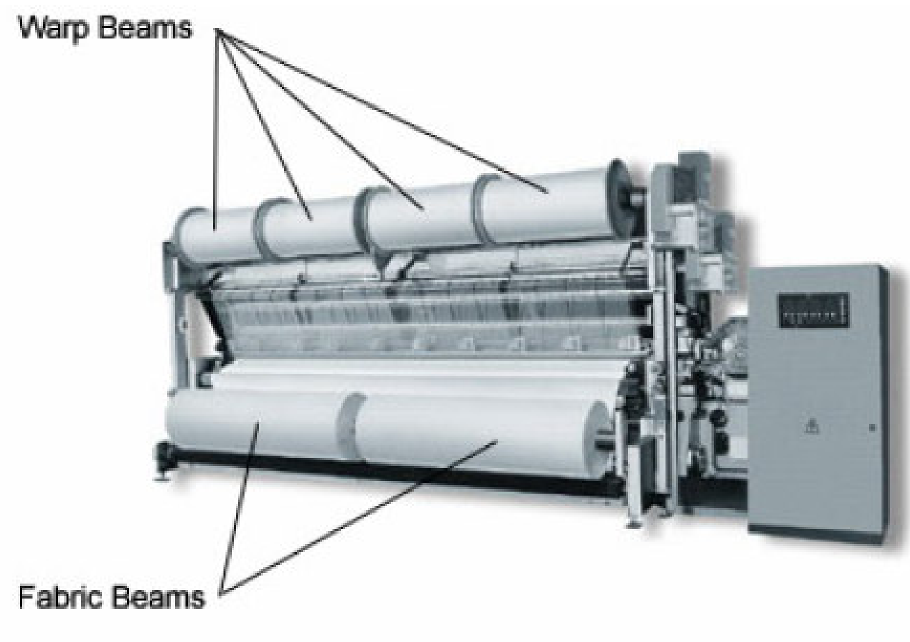


Figure 2.14 Warp knit machine

Raschel; Raschel is the other main warp knitting machine. Fabric from these machines may be of any weight or thickness from lace to carpet; the one feature they share is a pillar and inlay effect: wales like hand crochet chains forming the "pillar" with other yarns laid in to form patterns or the main body of the fabric, usually making up the right side.

Raschel machines have one or two needle bars (usually latch, but may be compound beard), set horizontally o wide or narrow machines with 1 to over 30 guide bars. Variations on raschel-type machines include crochet, ketten raschel and cidega machines. The latter, similar to raschel, can knit various fabrics side by side, and so is used for many narrow trims called "braids" such as gimps and ball fringe, like in Figure 2.14 [12].

2.5.2 Weft Knitting

Weft knitting is the more diverse, widely spread and larger of the two sectors, and accounts for approximately one quarter of the total yardage of apparel fabric compared with about one sixth for warp knitting. Weft knitting machines particularly of the garment-length type, are attractive to small manufacturers because of their versatility, relatively low total capital costs, small floor space requirements, quick pattern and machine changing facilities, and the potential for short production runs and low stock-holding requirements of yarn and fabric. A major part of the weft knitting industry is directly involved in the assembly of garments using operations, such as over locking, cup seaming and linking that have been specifically developed to produce seams with compatible properties to those of weft knitted structures. There are, however, production units that concentrate on the knitting of continuous lengths of weft knitted fabric for apparel, upholstery and furnishings, and certain industrial end-uses. In a weft knitting machine, even when the needles are fixed or are caused to act collectively, yarn feeding and loop formation will occur at each needle in succession across the needle bed during the same knitting cycle (seen in Figure 2.15 and Figure 2.16). All or a number of, the needles (A, B, C, D) are supplied in turn with the same weft yarn during the same knitting cycle so that the yarn path (in the form of a course length) will follow a course of the fabric passing through each needle loop knitted from it (E, F, G, H) [20]. Weft knitting machines are classified into two as; flat knitting machine and circular knitting machine.

Flat knitting machine; The first flat bar machine was demonstrated in 1862 and patented in 1865 by the Rev. Isaac Wixom Lamb, an American clergyman. He later changed the arrangement to the inverted V- bed shape patented by Eisenstuck.

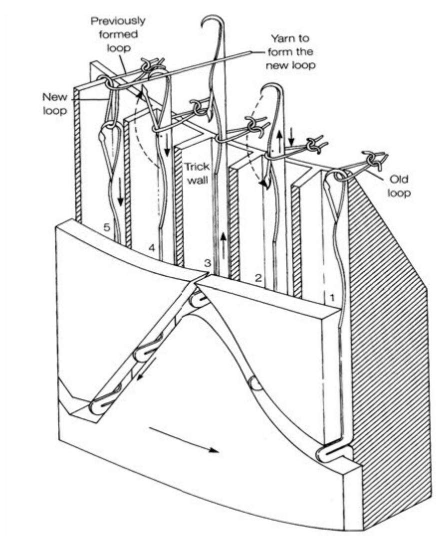


Figure 2.15 Loop formation on a circular knitting machine

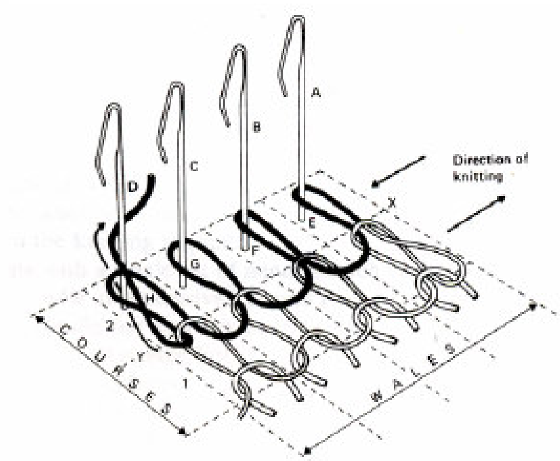


Figure 2.16 Width-wise knitting direction [1]

Two types of flat machine evolved. The widely used one is V-bed rib machine and the slower, more specialized one is flat bed purl or links-links machine. V-bed machines have two rib gated, diagonally-approaching needle beds, set at between 90 and 104 degrees to each other, giving and inverted V-shape appearance. Flat bed purl (links-links) machines have horizontal needle beds. They have been employed mainly in knitting simulated hand-knitted constructions of a specialty type, such as cable stitch, basket purl, and lace patterning. They use double-headed latch needles that are transferred to knit in either of two directly opposed needle beds. The non-knitting hook is controlled in the manner of a needle but by a slider that hooks onto on it. There is a set of sliders in each needle bed whose butts are controlled by the traversing cam-carriage to produce knitting or transfer of the needles.

These complex and slow machines are no longer built because the modern electronic V-bed machines can knit all the links-links designs using the facilities of rib loop transfer and needle bed racking. Early intarsia machines employed a different approach, using only one needle bed to knit solid color designs. Now, however, many modern V-bed machines have intarsia-patterning facilities and are no longer restricted to geometrical designs because the mechanically-controlled carrier stops have been replaced by more versatile electronic controls [20].

Circular knitting machine; The term circular knitting covers all weft knitting machines whose needle beds are arranged in circular cylinders and/or dials. Revolving cylinder latch needle machines produce most weft knitting fabrics and are of two main types, cylinder and dial machines and cylinder only machines. Cylinder and dial machines are of either the rib, or interlock type except in the case of certain effects fabrics such as eyelet. Cylinder only machines have only one set of needles, usually arranged in the cylinder [2].

2.6 CIRCULAR KNITTING MACHINE

In circular knitting machines shown in Figure 2.17 the elements of machine are seen. The types of fabrics produced by circular knitting machine are;

- Single Jersey fabric
- Rib fabric
- Interlock fabric
- Purl fabric

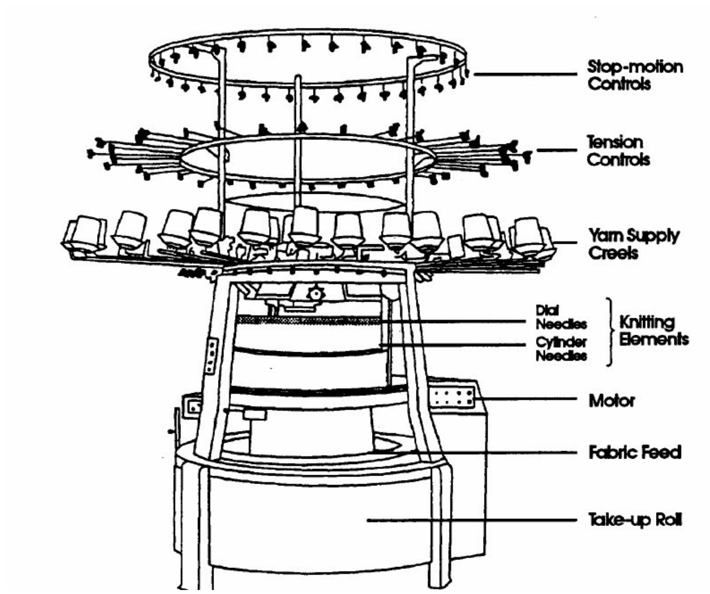


Figure 2.17 The elements of circular knitting machine

2.6.1 Types of Knitting

Single jersey fabric; This is the simplest of all knitted structures and is formed by the inter-meshing of a number of loops from side to side and top to bottom. Sometimes referred to as “plain knit” or “stocking stitch”, the construction is extensively used in the wool knitting industry (Figure 2.18).

<u>Single jersey fabrics characteristics are;</u>

- ❖ single sided
- ❖ thin/light-weight
- ❖ fast and efficient production
- ❖ edges curl, difficult to handle
- ❖ partially unstable, stitch distortion.

Rib fabric; The term “rib” covers a broad range of knitted structures from: 1x1, 2x1, 2x2,. The simplest rib fabric is a 1x1 and this is formed using 2 individual beds of needles whereby yarn passes from one bed to the other alternatively. (Figure 2.19)

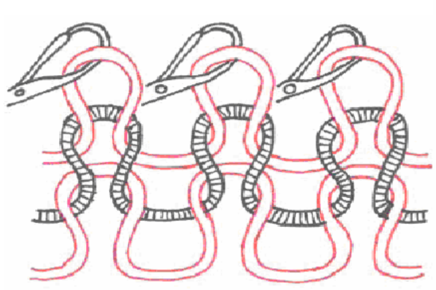


Figure 2.18 Single jersey fabric construction

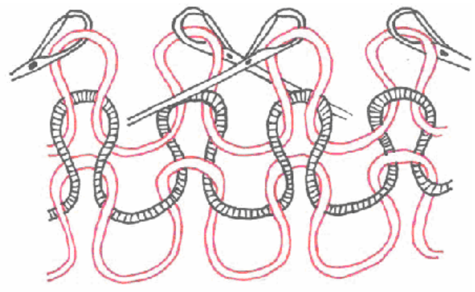


Figure 2.19 1*1 Rib fabric construction

1x1 rib fabric characteristics;

- double sided fabric
- thick/medium weight
- high width stretch/recovery
- balanced structure/fairly stable

Interlock fabric; This is quite similar in construction to the rib fabric as 1x1 rib is knitted alternately on opposite needles and it requires two knitted courses or traverses to complete one entire knitted row. Interlock is very popular on circular machines. (Figure 2.20)

Interlock fabric characteristics;

- double side fabric (same face and reverse)
- thick/heavy weight
- good width stretch/recovery
- balanced structure/very stable.

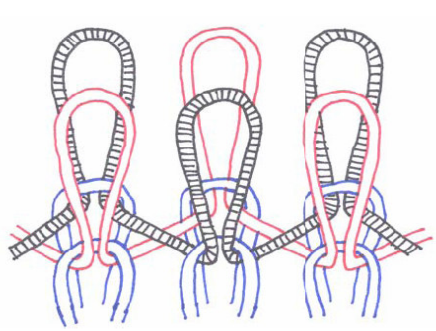


Figure 2.20 Interlock fabric construction

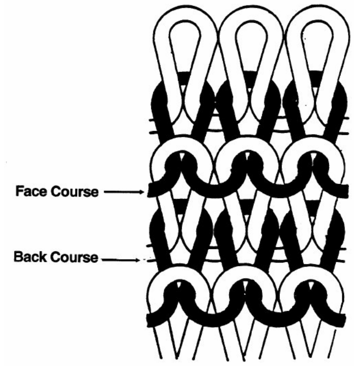


Figure 2.21 Purl fabric construction

Purl Fabric; 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 [12] (Figure 2.21).

<u>Purl fabric characteristics;</u>

- single sided fabric
- thick/medium weight
- limited stretch recovery
- reasonably balanced structure
- fairly stable

2.6.2 Main Terms Relating on Circular Knitting Machine

Loop; It is a basic unit consisting of a loop of yarn meshed at its base with previously formed basic units (stitches).

Machine pitch; It is defined as the distance between the centers of two neighbouring needles in one needle set, measured on the nominal machine diameter.

Stitch length; The length of yarn in one loop.

Course length; The length of yarn consumed at one feeder in one revolution of the machine.

Average stitch length; The course length divided by the total number of needles in the machine.

Number of feeders / Feeder density; A knitting feeder (working or production unit) is represented by one or several cams with a yarn presenting device, arranged in such a way, that they produce one course per revolution of the machine either on all needles or on those selected during patterning (partial course). [12]

Gauge; The number of needles per inch of circumference of the machine.

Diameter; The measurement of the diameter of the cylinder needle bed in imperial inches.

Inlay yarn; A yarn that is not actually knitted into a loop as part of a fabric but rather laid across the fabric and attached to the fabric with a tuck stitch or trapped between the back and the front of the fabric.

Course; A row of loops extending across the full width of the fabric.

Wales; A 'column' of loops that running down the length of the fabric representing the loops knitted by one needle.

Cylinder; The part of a knitting machine that holds those knitting needles that is in a vertical position during knitting. [18]

Dial; A horizontal plate which contains slot and horizontal needles.

Needle; an element which forms loops and wales

Sinker; an element on jersey machines which assists needles hold fabric during knitting

Tricks; slots which guide needles during knitting

2.7 QUALITY IN KNITTED FABRICS

Quality can be defined as the degree of nearness to wanted values. Preventing to decrease quality is more important than increasing quality. In textile sector the firms must fit standards and continue their quality, because for a consumer faultlessness is the most important parameter. In knitted fabrics the faults and the reasons of these faults are very different. The following explanations are expected to be helpful in trying to locate the causes of these faults easier.
The sources of faults could be;

- Faults in yarn and the yarn package
- Yarn feeding and yarn feed regulator

- ❖ Machine setting and pattern defects
- ❖ Machine maintenance
- ❖ Climatic conditions in the knitting plant

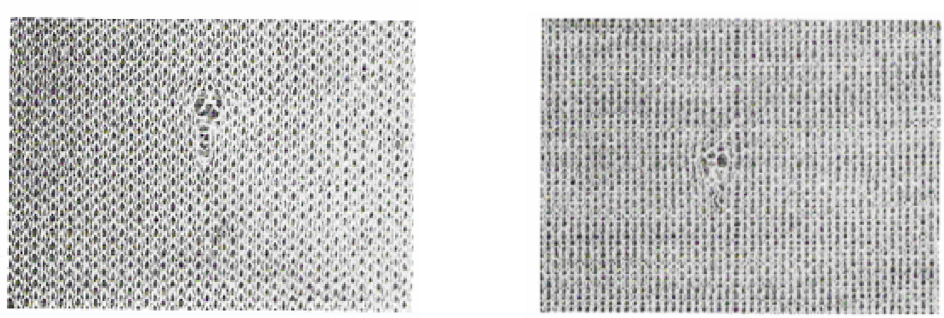
Taking prevention to produce faultless fabrics is more important and cheaper way than correcting faults on products. These preventive ways can be expressed as below:

- ❖ Machines must be settled to flat surface to prevent vibration.
- ❖ Yarn must be guided from bobbinning unit to knitting unit for enhancing tension.
- ❖ Yarn feeding units must be designed to enhance stable tension.
- ❖ Yarn guiders must be covered by porcelain for decreasing friction.
- ❖ Needles must be faultless.
- ❖ The count of yarns must be convenient to the fineness of machine.
- ❖ The canals in which needles move must be smooth and clean.
- ❖ Drawing tension must be convenient to yarn and fabric [19].

2.7.1 Faults in Knitted Fabrics

Faults very different in nature and appearance are often superimposed. The most common faults are:

Broken ends, holes or cracks; 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 (Figure 2.22).



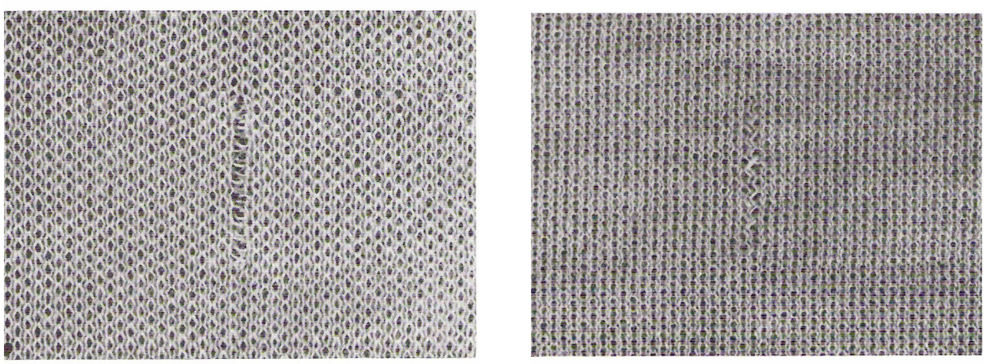
a) Hole on the front side b) Hole on the rear side

Figure 2.22 Fault: hole

Drop stitches; The yarn is too stiff and jumps away from the needle hook while being laid-in. This could be compensated by a re-adjustment of the yarn feeder or by increasing yarn tension. Yarn tension is not sufficient. Especially with jacquard structures with irregular yarn consumption and jerky processing, the yarn can shoot forward and puff itself up between yarn feeder and needle in such a way that it cannot be caught by the needle hook. The required tension compensation should take place as close as possible to the knitting zone (Figure 2.23).

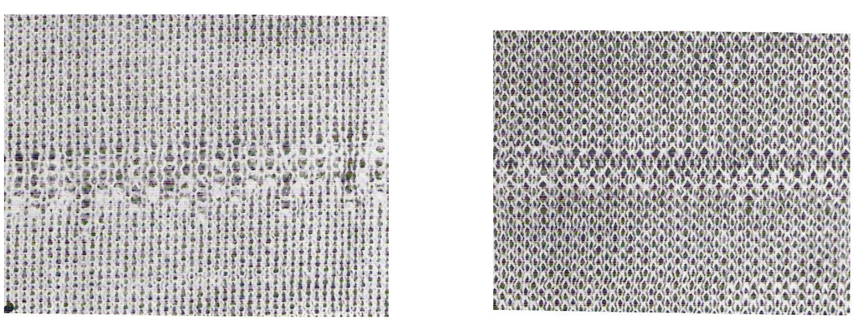
Cloth fall-out; The yarn is not stitched by several needles lying adjacent to one another. Cloth fall-out can occur after a drop stitch especially when an empty needle with closed latch runs into the yarn feeder and removes the yarn out of the hooks of the following needles (Figure 2.24).

Tuck or double loops; These faults appear 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. (Figure 2.25)



a) Drop stitches on the front side b) Drop stitches on the rear side

Figure 2.23 Fault: drop stitches



a) Cloth fall-out, front side b) Cloth fall-out, rear side

Figure 2.24 Fault: cloth fall-out

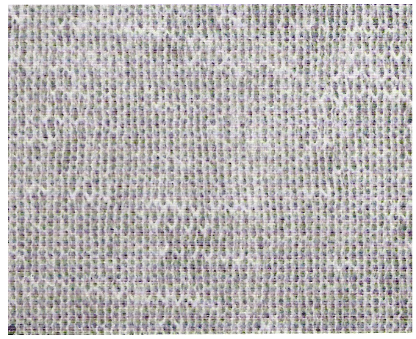


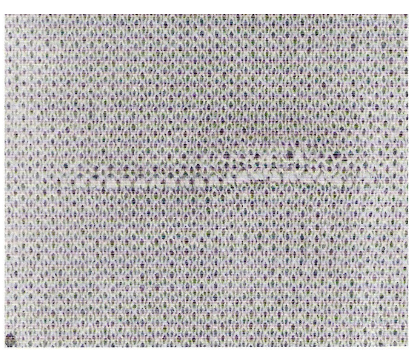
Figure 2.25 Fault: tuck loops

Snags; 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.

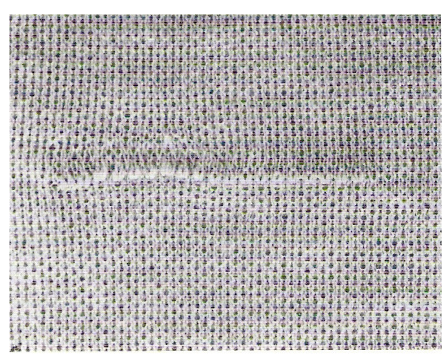
Bunching-up; This is largely influenced by the fabric take-up and whether it functions properly (Figure 2.26).

Vertical stripes; 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 (Figure 2.27).

Horizontal stripes; Horizontal stripes can be caused to the same extend 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.

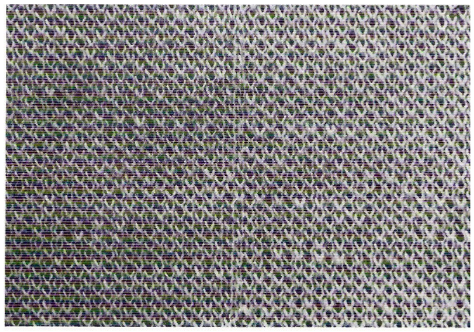


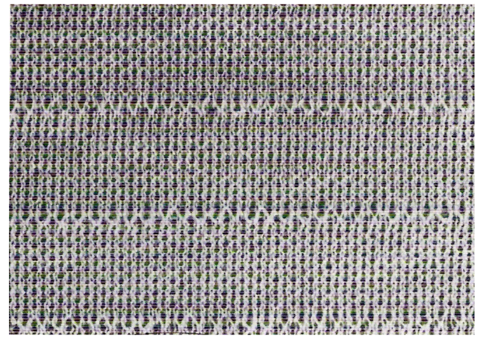
a) Bunching-up, front side



b) Bunching-up rear side

Figure 2.26 Fault: bunching-up





a)Fault: vertical stripes front side b) Fault: horizontal stripe, rear side

Figure 2.27 Fault: stripe

Soil stripes; 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.

Spirality: "Spirality" arises from twist stress in the constituent's yarns of plain fabric, causing all loops to distort and throwing the fabric wales and courses into an angular relationship other than 90 degree. 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 with 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 (Figure 2.28). The phenomenon of

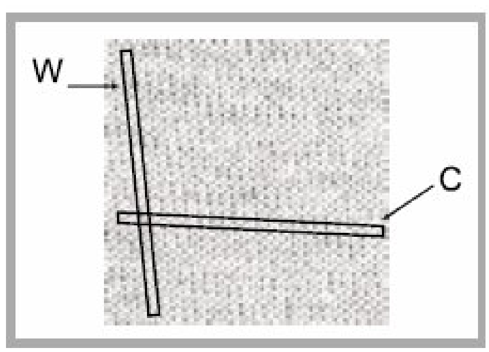


Figure 2.28 Spirality

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 unfortunately have not totally given a theoretical explanation or solution to solve this problem.

The problem of spirality has greatly affected the growth of the knitted fabrics. Some of the distortion resulting from spirality is 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 degrades 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 [12].

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.

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.

CHAPTER 3

SPIRALITY

3.1 INTRODUCTION

The knitted fabrics especially single Jersey fabrics are preferred the most in daily life. The reasons of this usage can be explained in various ways, as its elastic and light structure. First of all single jersey fabrics are produced easily and quickly. They have lighter weight and lower production cost and because of their smooth surface they are convenient to printing. However beside all the advantages these fabrics have quality problems like dimensional changes and deformations. The dimensional instability of knitted loop structure is seen. According to the ideal model the angle between the course and wale line must have been perpendicular. However, especially cotton single jersey fabrics have a tendency for the courses and wales to skew while relaxation progress. Spirality can be defined as a fabric condition resulting when the knitted wales and courses are angularly displaced from that ideal right angle and caused by the yarn liveliness. It is possible to use different terms such as torque, skew, bias. Bow is the fabric distortion in course direction caused by the multifeeder knitting or by the uneven take-down. This displacement of the courses and wales can be expressed as a percentage or an angle measurement in degrees. While the bow is almost improved by the finishing process, spirality is only temporarily improved by the same process and after the laundering spirality is repeated. Thus the spirality has an important influence on both aesthetic and functional properties of knitted fabrics and garments, the formation of spirality must be prevented by various methods related with yarn. Some of these methods are; the low-twist-lively yarns or the balanced plied yarns are preferred and S-twist and Z-twist single yarns are used at alternate feeders respectively [9].

Single Jersey fabrics are produced on circular knitting machines whose latch needle cylinder and sinker ring revolve through the stationary knitting cam systems, which together with their yarn feeders are situated at regular intervals around the circumference of the cylinder. The fabric is produced by the rotation movement of machine as a tubular form. The single jersey knitted structures, used widely in knitted garments, cause some problems, because of their unbalanced structures. The most important problem of the single jersey structure is fabric spirality, which affects all the fabric and creates big problems at the clothing step. It affects the garment as the displacements of the side seams and this causes an important quality problem. This problem is prevented during the finishing and dyeing processes by different methods. However these preventions are temporary, and after washing processes, on the clothes the displacement of side seam is occurred [10].

3.2 STRUCTURE OF SPIRALITY

In weft knitted fabrics produced with one needle system, the wales are not perpendicular to the courses as required but skew to the right or left, forming an angle of spirality with the perpendicular. This problem is often corrected in finishing by imposing distortion on the fabric so that the wales straighten out, being subsequently set in the new form. Setting may normally be achieved by using resins, heat, steam or mercerization, depending on the sort of fibers used. Setting by resins, steam, or dry heat is often not very stable and after repeated washings, skewing of the wales normally reoccurs. A consequence of this is that side seams of garments become distorted, normally rotating to the back and front of the body.

Spirality arises from twist stress in the constituent yarns of plain fabric, causing all loops to distort and throwing the fabric wales and courses into an angular relationship other than 90°. If the fabric is retained as a tube, the spirality throws the vertical alignment of the fabric away so that the wales lie at an angle to the edges of the fabric and slowly spiral around the fabric as seen in Figure 3.1.

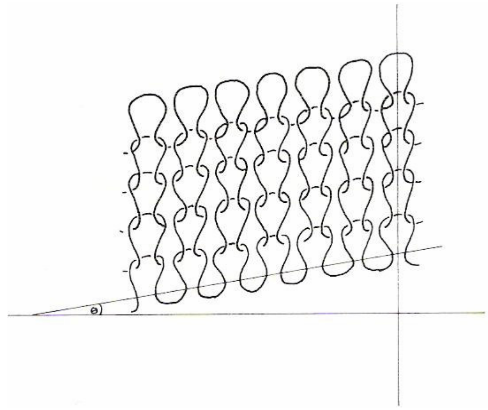


Figure 3.1 Angle of spirality in distorted plain fabric

3.3 CAUSES AND EFFECTS OF SPIRALITY

The main advantage of knitted fabric is comfort, easy to use and covering good appearance during use. The loops which make the structure of knitted fabric provide elasticity and elastic recovery. However this property is not always an advantage; it results in deformations named as spirality which is an unwanted fault. Single jersey fabrics are generally used to knit lingerie, under clothes, pajamas and t-shirts because these fabrics are easy and fast to produce and cheap; this wide using area of single jersey fabric makes the spirality very important. There are many ways to solve this problem but no solution is convenient to the end use of fabric. Another problem about spirality is that single jersey fabrics are washed more; and if this washing is not done correctly, spirality increases shown in Figure 3.2.

Spirality problem is seen on end products' side seams changed especially fabrics produced with faults. More clearly if a fabric is produced as square seen in Figure 3.3 (a); it turns to parallel side in Figure 3.3(b) after washing.

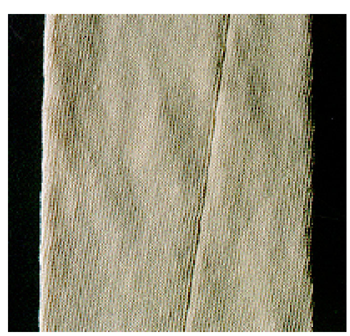
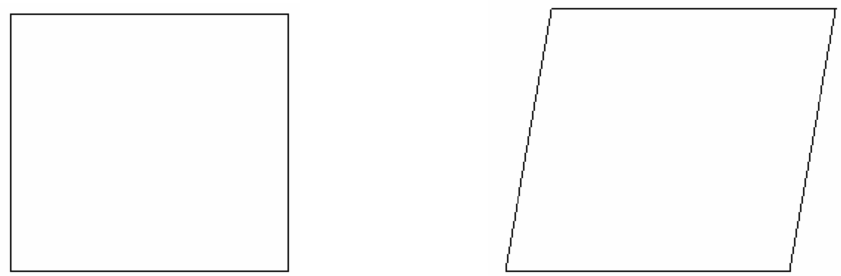


Figure 3.2 Increased spirality after laundering

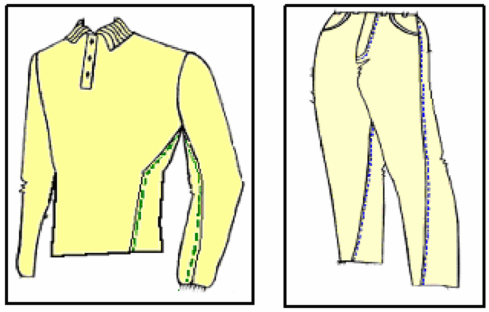


(a) Square product (b) Parallel side product

Figure 3.3 Product's view

On ready made clothes spirality becomes more important problem. Different from woven clothes; knitted clothes must be cut separately. If the fabric is not cut and sewn by this way the result will be as illustrated in Figure 3.4. There are two clothes of which side seams are changed from original position. There are many standards to measure spirality but in this thesis IWS 276 is used. According to this standard spirality is the angle between course and wales different from 90° (Figure 3.5). As seen in Figures 3.6 a and 3.6 b loops tend to the left or right according to twist direction of yarn and rotation direction of machine [2, 3]. Until today many people have tried to solve spirality problem. Even though there is no exact solution but at least the reasons of spirality are investigated. The solution methods and their results can be explained as below:

- Spirality caused by yarn
- Spirality caused by machine
- Spirality caused by finishing
- Spirality caused by washing and drying



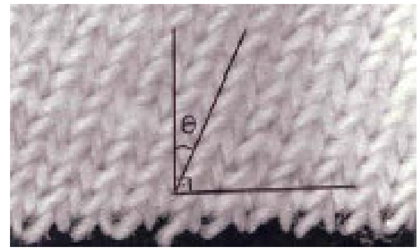
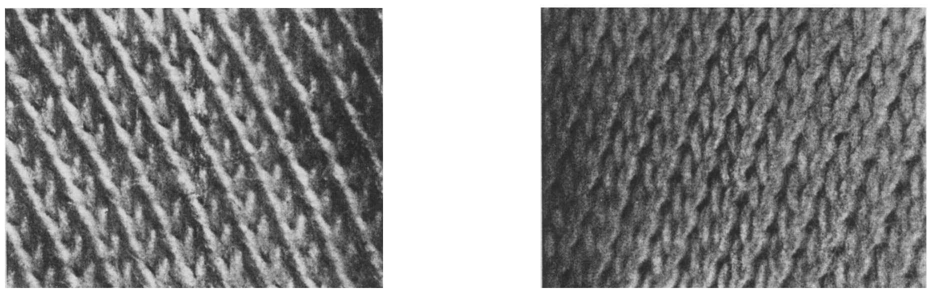


Figure 3.4 Spirality on clothes   Figure 3.5 Angle between course and wale



(a) Spirality to the right side   (b) Spirality to the left side

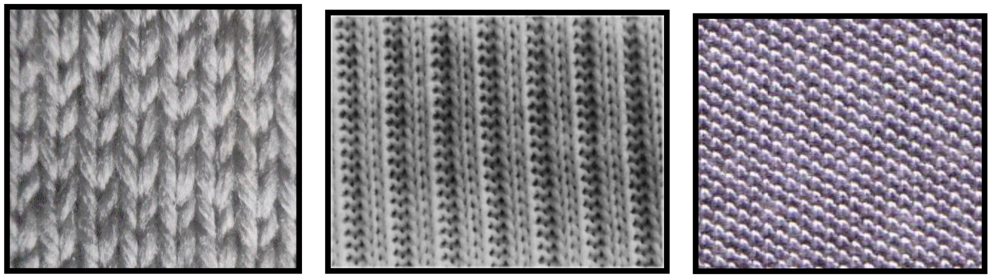
Figure 3.6 Spirality directions [2, 3]

3.3.1 Spirality Caused by Yarn

Physical properties as raw material, production method, twist, ply and count of yarn to produce single Jersey fabric affect spirality of the fabric. The processes to avoid spirality can be explained briefly as below.

If the fabric is knitted as rib form (Figure 3.7 b) or as lacoste form (Figure 37 c) instead of plain form (Figure 3.7 a) the fabric will be more balanced [7]. The movement of loop in the fabric is limited and because of this loop limitation spirality is prevented but at the same time the fabric loses elasticity and according to end uses of single jersey fabrics, elasticity is an important property.

Tighter knitting fabric prevents the moving ability of loop in a fabric so spirality is avoided at the same time [20]. However this method can not be used in practical because the fabric again loses elasticity and the weight of fabric increases and the physical properties of fabric are changed. Production cost and time of fabric increases and the advantages of using single jersey fabric decreases. In Figure 3.8 loose, medium and tight knitted forms of polypropylene are seen.



a. Single jersey fabric b. Rib fabric c. Lacoste fabric

Figure 3.7 Knitted fabrics

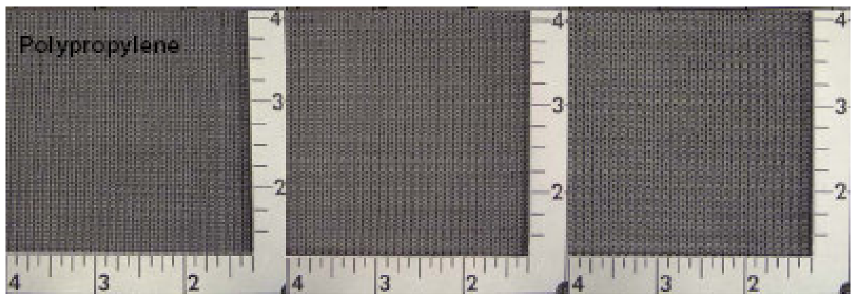


Figure 3.8 Loose-Medium-Tight knitted PP fabrics [20]

3.3.1.1 The effect of yarn twist and yarn liveliness

Previous studies have agreed that yarn twist multiple and the tendency of the yarn to snarl due to unrelieved torque are the most important factors affecting the spirality of single jersey fabric [21, 22]. Workers have also argued that neither the yarn twist nor the snarling tendency alone can be decisive in determining the degree of wale inclination. On the other hand, an increase in twist multiple has a pronounced effect on spirality [2].

The spirality problem has been investigated by several researchers [23]. Krishnakumar, Dasaradan, Subramaniayam (2004) have studied the effect of fiber quality index on the fabric spirality. They have determined that spirality depends on yarn twist liveliness. Twist liveliness is a yarn property which gives an indication of tensional energy present in the yarn. It is dependent on the yarn twist; the maximum value of twist liveliness occurs for higher twist content. Since spirality appears generally in knitted fabrics produced from single yarns, it is decided to produce a range of single yarn samples from cotton having different FQI values with different twist factors with a view to investigating the effect of FQI, twist and twist liveliness on spirality. There is almost a linear relationship between the level of twist and twist

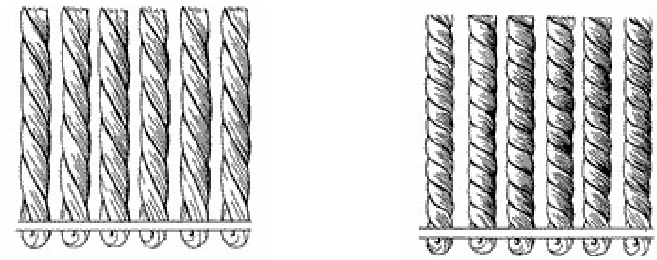
Table 3.1 Effect of twist liveliness on spirality [2]

	A			B			C			D		
T.M	**3.2**	**3.5**	**3.8**	**3.2**	**3.5**	**3.8**	**3.2**	**3.5**	**3.8**	**3.2**	**3.5**	**3.8**
Twist Liveliness (CM)	19.69	25.99	28.96	17.82	22.24	27.71	23.14	27.69	30.76	19.62	21.54	23.55
Spirality (Degree)	4.2	6.5	7.3	3.6	6.1	6.9	5.9	7.1	7.3	4.9	5.1	5.6

liveliness values. With increasing T.M value the twist liveliness values increase. The reason for this linear variation is due to the amount of energy stored in twisting. Higher the twist liveliness, greater will be the energy stored. The values of spirality in degrees are tabulated in Table 3.1.From Table 3.1, it is clearly observed that higher the twist liveliness value, the severity of spirality also becomes higher. For the minimum twist liveliness value of 17.82, the spirality is 3.6, for the maximum twist liveliness value of 30.76, the spirality is 7,3. So we can say that spirality increases with increasing twist liveliness value [23].

- If the fabric is knitted by yarns which have low twist liveliness, spirality decreases. Twist liveliness is decreased by giving fixation to the yarn before knitting. This method is used in practical but to use fixation the fiber must have thermoplastic property. So this method is not convenient to the all fibers. Moreover, the knitting machines are worked in determined humidity conditions and humidity changes fixation on the yarn so in a fabric yarn shows different characters caused by different fixation. Another problem is the hand of fabric loses softness; fixation makes fabric stiff.

- Using low twisted yarn is another solution, but low twisted yarn results another faults so it is not a solution a lone. Low twisted and more twisted yarns are seen in Figure 3.9 a and Figure 3.9 b respectively. In the literature, it is concluded that yarn twist multiple has been ranked as the principal cause of spirality, the angle of spirality decreasing as the twist multiple decreases. Yarn “torque” which



a. Low twisted yarn b. More twisted yarn

Figure 3.9 Twisted yarns

causes the yarn to snarl, has also a great influence on spirality, and torque relief reduces this effect [2].

3.3.1.2 The effect of yarn plying

One way of making twist stable yarns is by plying two identical single yarns and twisting them in a direction opposite to the spinners' direction of twist. Furthermore, such yarns can be made even more stable if package dyed in this form. From the literature it is concluded that the angle of spirality was zero in both the dry and fully relaxed states. This seems to be an effective way of completely avoiding spirality, even though cost is an important paramater.

- Using plied yarns: if Ne 30/1, $\alpha_m = 100$, Z twisted two cotton yarns (Figure 3.10), are plied S direction; the count of plied yarn is Ne 15/2 S twisted and $\alpha_m = 50$. It means the twist of yarn decreases half. This method is used to knit coarse fabrics but to knit finer clothes like t-shirts; this method is very expensive. Because cost of spinning another yarn, cost of spinning finer two yarns, necessity to use finer yarns in some conditions, and cost of plying must be added to production cost; so, this method is not advised to producers [3].

3.3.1.3 The effect of plaiting

According to result of Araujo and Smith's experiment [10] Table 32 is obtained. According to Table 3.2 fabrics 21 and 22 were produced by plaiting yarn 1 (Z twist) with yarn 2 (S-twist). In fabric 21, yarn 1 was knitted on the technical face and fabric 22; yarn 2 was knitted on the technical face. Both 21 and 22 showed no spirality in either the dry or in the fully relaxed state. This behavior was due to the balancing effect of having S- and Z-twist yarns knitted in a plaiting relationship. Plaiting is an effective technique to produce spirality-free fabric even though there are costs and other aspects that must be considered. The results are shown in Table 3.2 where we see that using yarns of different twist direction as ground and binder can reduce the angle of spirality very drastically to within acceptable levels. This is indeed a technique worth exploring, since it leads to excellent improvements without greatly affecting costs [2]. Using S twisted yarn in one row and using Z twisted yarn in another row (Figure 3.11). The row of S twisted yarn tends to the left side and the row of Z twisted yarn tends to the right side; so there is no spirality in the fabric. The fabric knitted by this method has a zigzag form and it is not liked by all people [26]. This method is very cheap but needs planning and organization.

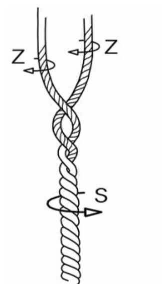


Figure 3.10 S twisted yarn plied with Z twisted yarns

Figure 3.11 Knitted fabric with S twisted and Z twisted yarn

Table 3.2 Fabric specifications [2]

				Dry relaxed		Fully relaxed		
Fabric no.	Yarn no.	l, cm	K, tex$^{1/2}$ cm^{-1}	θ, °L/R	c/w	θ, °L/R	c/w	Yarn condition
1	2	0.367	14.45	20.0 L	1.23	18.0 L	1.30	untreated
2	1	0.367	14.82	19.0 R	1.09	16.0 R	1.35	untreated
3	4	0.350	15.22	13.0 L	1.30	14.0 L	1.35	steam set 1 cycle
4	3	0.370	14.44	12.0 R	1.18	14.0 R	1.30	steam set 1 cycle
5	5	0.360	14.83	8.0 R	1.60	11.5 R	1.35	steam set 9 cycles
6	6	0.350	15.22	10.0 L	1.43	13.5 L	1.35	steam set 9 cycles
7	7	0.360	15.20	6.0 L	1.45	9.0 L	1.45	4% PVA
8	8	0.340	16.10	8.0 R	1.45	12.0 R	1.45	4.5% PVA
9	9	0.370	14.80	5.0 L	1.59	9.0 L	1.45	10.2% PVA
10	10	0.380	14.40	6.0 R	1.35	12.0 R	1.39	13.4% PVA
11	11	0.390	14.04	16.0 R	1.38	17.0 R	1.45	0.5% LMP untreated
12	12	0.390	14.04	11.0 R	1.30	10.0 R	1.24	0.5% LMP heat set oven
13	13	0.388	14.12	12.0 R	1.53	15.0 R	1.50	10.3% LMP heat set oven
14	14	0.368	14.48	12.0 R	1.68	12.0 R	1.45	0.5% LMP heat set in text. machine
15	15	0.363	15.09	8.0 R	1.89	9.0 R	1.62	10.3% LMP heat set in text. machine
16	16	0.380	15.23	2.0 R	0.76	9.0 R	1.29	dyed
17	17	0.380	15.00	7.5 R	0.83	10.0 R	1.29	dyed
18	18	0.579	14.75	0.0	1.14	0.0	1.38	plied and dyed
19	19	0.293	15.21	1.0 R	1.86	12.5 R	1.56	steam set 9 cycles knitted wet
20	20	0.290	15.39	1.0 R	1.82	19.0 R	1.61	steam set 9 cycles knitted wet
21	1 + 2	0.629	12.31	0.0	1.34	0.0	0.74	plaited Z on tech. face, untreated
22	2 + 1	0.629	12.31	0.0	1.03	0.0	0.74	plaited S on tech. face, untreated
23	B1	0.520	–	1.0 R	1.02	10.0 R	1.38	untreated
	G1	0.520						
24	B1	0.530	–	2.0 R	1.07	2.0 R	1.40	untreated
	G2	0.540						
25	B2	0.530	–	0.0	1.05	1.5 R	1.40	untreated
	G1	0.530						

3.3.1.4 The effect of yarn treatment

According to result of Araujo and Smith's experiment, Yarn 1 and 2, which were untreated, showed the highest tendency to snarl. This is because the spiral configuration of the path of the fibers was in a very unstable state, and therefore the untwisting "couple" was the highest. Furthermore, S- and Z-twist yarns had untwisting couples, which operated in opposite directions. These yarns knitted well under positive feed conditions, but there was a tendency to snarl between the package and the positive feed unit. The fabrics knitted with these yarns (1 and 2) exhibited the highest angles of spirality, which were higher when the fabrics were dry relaxed. This is probably because the high level of loop distortion due to yarn liveliness decreased after the fabrics were fully relaxed.

During loop formation, the loop is deformed due to the various stresses imposed by the knitting process. These deformations are normally recovered during fabric relaxation, as the loop tends to overcome frictional restraints to assume a natural shape within the space available to move. This is a function of tightness of the fabric construction. If the yarn itself is lively enough to overcome some of the frictional restraints, this could possibly explain the fact that for yarns 1 and 2, the angle of spirality was higher in the dry relaxed state [2].

3.3.1.5 The effect of yarn spinning technology

Yarn physical properties are important to the knitting process and the characteristics of the fabrics produced. During the knitting process, it is important that the yarn is fed from the yarn package to the needles without problems caused by slubs, knots, snarls, and lint. During loop formation, the tension in the yarn increases rapidly to reach a maximum before the knitting point, depending on the amount of yarn robbing back that may occur. This maximum tension should preferably not exceed the elastic limit of the yarn, so that yarn dimensions and strength are not affected. At higher tensions, the viscoelastic nature of the yarn may cause deformations to be recovered over a period of time. If the knitting tension is too high, however, the yarn is deformed plastically and drafting may occur, making the yarn thinner and giving rise to a larger and weaker loop. When the knitting tension exceeds the breaking load of a particular point of the yarn, a hole may appear in the fabric. Thick places in the yarns may restrict yarn flow during loop formation, causing a sudden rise in tension and

Table 3.3 Fabric specifications [3]

				Dry relaxed		Fully relaxed			
Fabric no.	Yarn no.	l, cm	K, $tex^{1/2}\ cm^{-1}$	θ, °L/R	c/w	θ, °L/R	c/w	Fiber content	Spinning tech.
26	21	0.388	14.83	9.0 R	1.34	16.5 R	1.29	100% cotton	ring
27	22	0.389	14.43	6.0 R	1.32	10.0 R	1.38	100% cotton	rotor
28	23	0.388	14.88	14.0 R	1.40	20.0 R	1.32	100% cotton	friction
29	24	0.295	15.12	13.0 R	2.02	20.0 R	1.70	100% cotton	friction
30	25	0.295	15.00	4.5 R	2.11	8.5 R	1.69	100% cotton	air jet
31	26	0.387	14.90	10.5 R	1.32	13.0 R	1.28	50/50 cotton/poly	ring
32	27	0.295	15.10	7.5 R	1.93	7.5 R	1.43	50/50 cotton/poly	ring
33	28	0.280	14.65	7.5 R	1.83	10.0 R	1.36	50/50 cotton/poly	ring
34	29	0.388	14.68	2.0 R	1.43	2.5 R	1.34	50/50 cotton/poly	rotor
35	30	0.296	15.05	0.0	1.93	1.0 R	1.47	50/50 cotton/poly	rotor
36	31	0.280	14.93	6.5 R	2.05	6.0 R	1.53	50/50 cotton/poly	rotor
37	32	0.294	15.24	5.0 R	2.00	0.0	1.58	50/50 cotton/poly	air jet
38	33	0.280	14.29	5.0 R	2.19	4.5 R	1.87	50/50 cotton/poly	air jet

* l = loop length, K = tightness factor, θ = angle of spirality, °L/R = degrees to left/right, c/w = courses/wales = loop shape factor.

consequent break. On the other hand, thin places may not be strong enough to withstand the knitting tension. These problems may become more critical when knitting light count fabrics on machines with high cut. As far as the knitted fabric is concerned, a low twisted, even yarn that does not pill is the main requirements to achieve a soft hand, regular loops, and a good appearance.

The fabric characteristics are given in Table 3.3. Generally speaking, 100% cotton yarns showed a greater angle of spirality than the 50/50 blend in the fully relaxed state. In the dry relaxed state, the results are inconsistent. For the 100% cotton yarns, spirality increased considerably after the fabrics were fully relaxed, whereas for the 50/ 50 blend yarns, the results were inconsistent.

Figure 3.12 shows the relationship between the angles of spirality, twist multiple, and yarn snarling with respect to yarn spinning technology for the 100% cotton yarns. The angle of spirality increases with twist multiple, and the latter is related to the spinning technology used. Therefore, the angle of spirality decreases as follows: friction > ring > rotor > air jet. This applies both to the dry relaxed and fully relaxed state. With respect to the relationship between the snarling tendency and yarn spinning technology, the results are inconsistent.

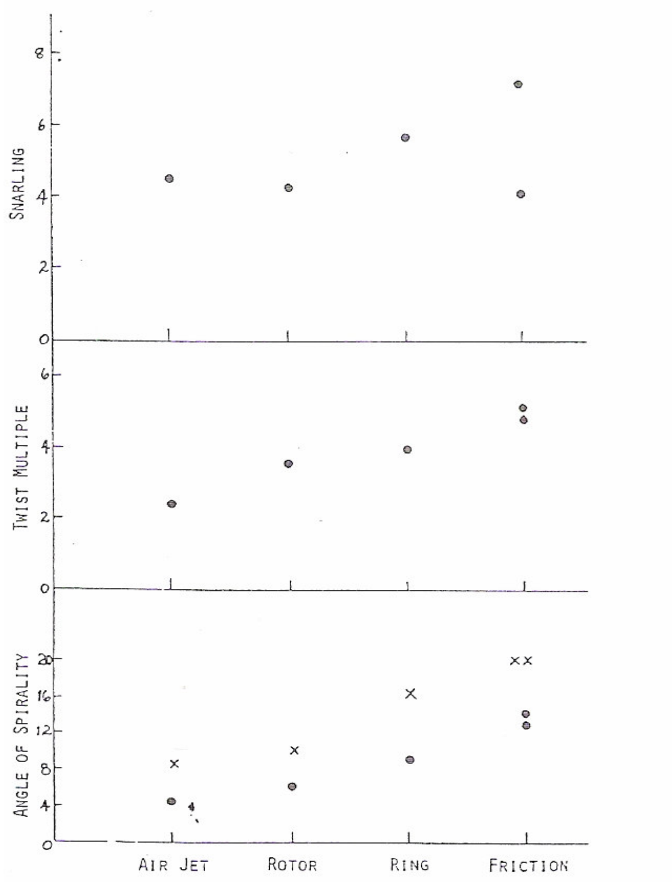


Figure 3.12 Variation of angle of spirality, twist multiple, and snarling tendency with spinning technology (100% cotton yarns)(•)dry relaxed,(x) fully relaxed[20],

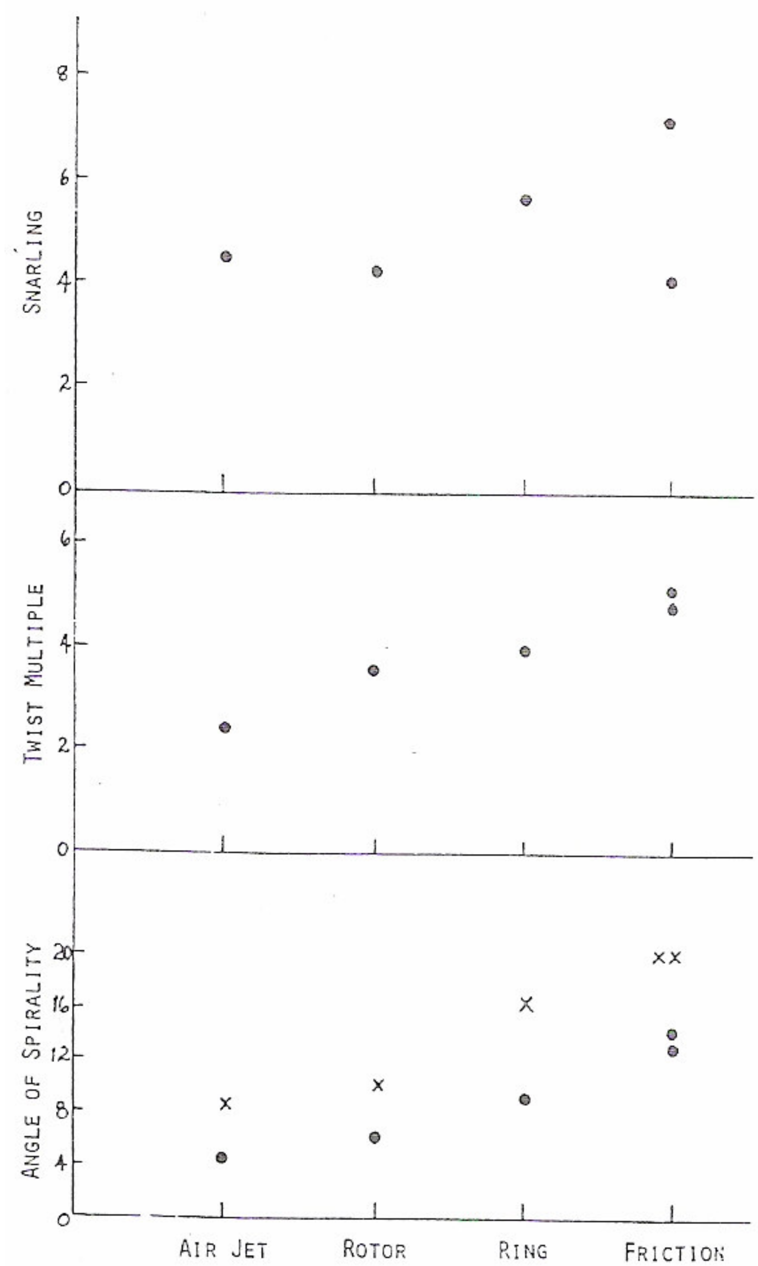


Figure 3.13 Variation of angle of spirality, twist multiple, and snarling tendency with spinning technology (50/50 blend yarns): (•) dry released (X) fully released

Figure 3.13 shows the relationship between fabric spirality, twist multiple and yarn snarling with respect to spinning technology for the 50/50 blend yarns. Both the air jet and the rotor spun yarns which have the lowest twist multiples and tendency to snarl, have the lowest angles of spirality in both the dry relaxed and fully relaxed states. In effect, some of the fabrics have no spirality at all, and in the fully relaxed state, three fabrics had angles of spirality below 2.5°.

The performance of both air jet and rotor spun yarns was extremely good, but within this group, there was inconsistency between the relationships of twist multiple, tendency to snarl, and angle of spirality. Yarns manufactured by different spinning technologies perform differently with respect to their tendency to produce spirality in jersey fabrics. Friction spun yarns made of 100% cotton produce fabrics with the highest degree of spirality, followed by ring spun yarns. Both rotor spun and air jet yarns produce fabrics with a low degree of spirality. In general, the 50/50 cotton/polyester blends have a lower tendency to produce spirality in fabrics than the 100% cotton yarns, probably because steam setting is more effective with polyester than with cotton. With both air jet and rotor 50/50 blend yarns, it was possible to knit fabrics without any spirality. Note, however, that in the fabrics we used, there was a direct relationship between the angle of spirality, twist multiple, and the type of yarn spinning technology used [20].

3.3.2 Spirality Caused by Machine and Solution Methods

Single jersey fabrics results in spirality are knitted with circular knitting machines with many feeders. The fabrics knitted by circular knitting machines are in a tube form, Figure 3.14. For example in Figure 3.15 there is a 30” machine with 80 feeders; by one full revolution of this machine 80 rows are knitted at the same time.

Figure 3.14 Fabric in a tube form

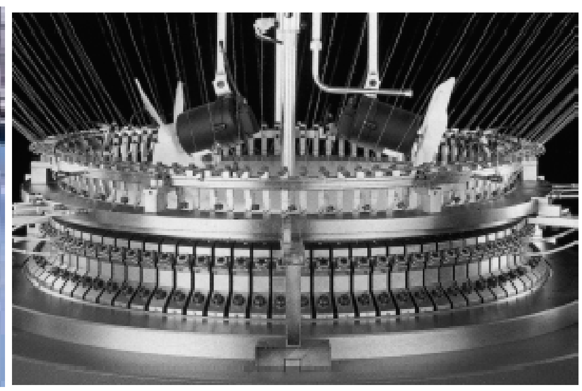


Figure 3.15 Circular knitting machine

If on a machine there are following two feeders while first feeder is knitting first row; second feeder knits second row. More clearly; if there is a colored yarn on first feeder and there is white yarn on all feeders; colored yarn turns around the tube fabric helically as seen in Figure 3.16. This knitting form makes spirality on a fabric; so dependently yarn production technology and raw material increasing the number of feeders results in increasing spirality. To prevent this spirality there are two methods: first one is using less number of feeders second one is working with open width fabrics and making fabric stable in finishing [3].

3.3.2.1 The effect of number of feeds

Araujo and Smith [2] studied the effect of machine, yarn and fabric properties on the fabric spirality. They determined that spirality depends on machine cut, feed density, machine rotation direction, loop shape, yarn twist value (twist liveliness) and yarn twist direction. The angle of spirality due to the number of feeds on the knitting machine depends not only on the number of feeds but also on the shape of the loop in a particular state of relaxation of the knitted fabric and on the number of active needles in the knitting machine, which in turn depends on machine cut and diameter.

They suggested that in some cases spirality could be totally eliminated by using a yarn that gives a particular angle of spirality in one direction, and knitting on a machine with a number of feeds that would give the same angle of spirality in the opposite direction. This may be of some practical importance to knitters, since they would have some guidance as to the yarns they could safely knit on a particular knitting machine. In some cases, however, it is possible to design yarns that give no

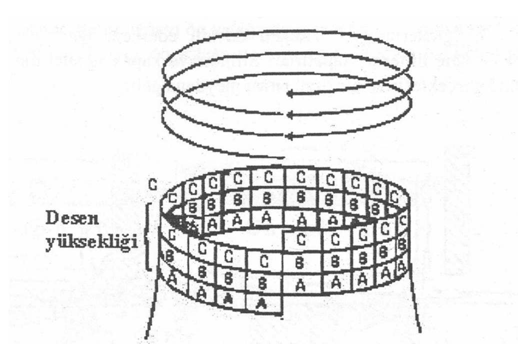


Figure 3.16 Helical positions of rows in a fabric with three feeders [19]

spirality, and for these, the total fabric spirality would be to the left. They inferred that the use of a large number of yarn feeds on a knitting machine can very often be beneficial rather than detrimental from a spirality point of view. At the present time, however, there is a limitations to the feed density that is possible in practice on a knitting machine, such as the cam angle (which cannot be increased beyond certain limits and productivity), which increases as the number of feeds increases. Thus for a 26″ diameter machine, the maximum number of feeds available is approximately 130. In this context, it was interesting to calculate the number of feeds needed to cancel a yarn spirality of 7°. By referring to line three of Table 3.4, which shows the number of feeds needed for different machine cuts to achieve 7° of spirality, it can be seen that this would not be possible to obtain in all cases with present day technology [2]. F represents Number of feeds.

- During knitting weight can be changed; it affects the tightness of fabric. Decreasing weight results in more slacked fabric so this fabric can be deformed easily; so weight must be increased as soon as possible. But increasing weight results in increasing production and dying cost. Tightness factor (defined as the ratio of square root of yarn count to loop length) prevents a measure of the freedom of loop movement in the knitted fabric construction and thus greatly affects fabric spirality.

Table 3.4 Relationship between angle of spirality (θ) and number of feeds (F) in the stable state (simulation for a 26″ diameter machine) [2].

	Machine cut									
	12	14	16	18	20	22	24	26	28	30
No. of needles	980	1143	1306	1470	1634	1797	1960	2124	2287	2450
No. of feeds for $\theta = 7°$	156	182	208	235	261	287	313	339	365	391
Angle of spirality for[a]										
$F = 64$	2.88°	2.47°	2.16°	1.92°	1.73°	1.67°	1.44°	1.33°	1.23°	1.15°
$F = 78$	3.50°	3.00°	2.53°	2.34°	2.10°	1.91°	1.75°	1.62°	1.50°	1.40°
$F = 104$	4.66°	4.00°	3.51°	3.12°	2.80°	2.55°	2.34°	2.16°	2.00°	1.87°
$F = 130$	5.83°	5.00°	4.38°	3.89°	3.50°	3.19°	2.92°	2.70°	2.50°	2.33°

The loop produced from a twist-lively yarn will yield higher spirality in a fabric with lower tightness factor. At each level of yarn twist factor, the degree of fabric spirality decreases linearly with fabric tightness factor. In other word, tightly knitted fabrics exhibit smaller degrees of spirality. In a more tightly knitted fabric, the movement of a knitted fabric, the movement of a knitted loop is restricted, and thus spirality is reduced [4].

- The power of recovery in single jersey fabrics that have been stretched is generally inadequate, and therefore spandex is increasingly used to impart a greater level of stretch and more dimensional recovery than can be achieved with cotton alone. The use of spandex has resulted in fabrics fit better on the body like a second skin and has good shape retention without any deformation throughout the life of the garment [8].

In brief loops are gained elastic recovery ability by elastomer so the loops can cover original shape; and the clothes produced from elastomer skewness is not seen. At this time it is thought to use elastomer with all yarns but it is impossible. Because elastomer increase the production cost, the physical properties of fabric change.

- The direction of machine rotation by itself has some influence on spirality. There is a slight inclination of the loops in the direction of running. This is possibly due to a tension imbalance between the two legs of the loop during stitch formation, but this effect is hardly noticeable and can be disregarded for all practical purposes [2].

- The direction of spirality depends on the twist direction of yarn as said before. If it is thought the direction of rotation changes the spirality so in order to minimize spirality, Z-twist yarns should be knitted on machines that rotate clockwise and S-twist yarns should be knitted on machines that rotate counterclockwise [2].

3.3.3 The Effect of Finishing on Spirality

3.3.3.1 The effect of relaxation treatments

Fabric relaxation (dry as well as wet) treatments can remove the residual knitting tension in the yarn introduced during the knitting process. The relaxation treatment relieves the residual yarn torque as a result of changes in the fiber's molecular structure and the increasing yarn mobility; this phenomenon promotes higher spirality. According to another hypothesis, water relaxation causes swelling and contraction of yarn dimensions. The rotation movement of a loop within the knitted structure is thus restricted, leading to reduced fabric spirality. Whether spirality will increase or decrease as a result of water relaxation treatment depends on the predominance of one factor over the other [4].

3.3.3.2 The Effect of Stenter Finishing on Spirality

Since natural and synthetic fibers undergo different responses to heat and to moisture, procedures for the dimensional stabilization differ from one fiber type or fiber blend to another. This is particularly true concerning desirable setting temperatures and the order in which setting is conducted in a textile processing sequence. This is readily observed by comparing the sequences for different types of fibers and even for the same types of fibers with different constructions. The tenter frame is the apparatus most frequently used to heat set all types of fabrics. It consists of three parts: (a) an entry frame and chain whereby the fabrics are dimensionally stabilized by clips or pins before heating, (b) a heating zone that varies in temperature from 140-230°C depending on the fiber type and fabric construction, and (c) a delivery system that holds the fabric under minimum tension while cooling to retain the desired dimensions. Because of the importance of the tenter frame, there have been several studies to measure and predict the appropriate or required amounts of moisture and heat necessary to stabilize fabrics dimensionally in it as well as to conserve energy during processing [24]. The main function of the stenter is to impart dimensional stability to the fabric. Fabric structure is stabilized by controlling the longitudinal and transverse tension and heat setting the fabric in tension. Length is controlled by positive overfeeding, whereas width is controlled by mounting the fabric on parallel running chains. Tentering is a critical process, and determines the dimension stability of the fabric and shrinkage during use. These machines normally run at around 0-150m/min., depending on the type of machine, the process used, and the fabric. Overfeeding can be carried out between -15% and +60%. Heat setting is done in a long closed chamber, where the fabric is dried at a high temperature by means of hot air. Among the different products used in the finishing of textiles, the most eco-friendly products are formaldehyde-based cross-linking agents, crease-resistance and dimensional stability. During their application, the evolution of free formaldehyde can arise due to unreacted formaldehyde in the product, liberation of formaldehyde during the cross-linking reaction, and slow generation of formaldehyde during the storage of resin-finished fabrics and garments [25]. Spirality is reduced with this process because; fabric structure is stabilized by controlling tension and heat setting the fabric in tension.

3.3.4 The Effect of Washing and Drying on Spirality

In this part, the washing and drying recommendations will be explained. The bought product is the end product and generally this product has a straight shape. However most of the consumers complain about products after washing that the products lose their shapes. There are two reasons of this deformation: First; the fabric had produced with faults and some temporary finishing was given to the fabric; and after washing product lose this finishing and of course lose shape. The fabric turned to parallel side shape as said before. Second type fault is related with the consumer; consumer does not care the washing recommendations. All the fabrics are not washed at same conditions. Some fabrics are machine washable, some are not; some fabrics are dry cleaned, some are not. If a fabric is machine washable; consumer must care the temperature. If the force between clothes is thought; the amount of clothes in machine is important. Like washing; drying is important too. All the fabrics' drying must be different. Some are tumble dryable, some are not; some are line dried, some are hanged dried. Especially blouses must be dried on a flat surface. After drying clothes must be ironed correctly; so the fabric covers the shape for a long time.

CHAPTER 4

MATERIALS AND METHODS

4.1 INTRODUCTION

Global demand for knitwear is growing at faster rate than that of woven fabrics, currently around 50% of clothing needs in the developed countries is met by knit goods. The demand is ever increasing even though these knitted fabrics and garments lose their original shape in a shorter span of time when compared with woven fabrics and garments. Spirality in knitted fabrics depends on yarn and machine parameters. Any error in the selection of raw material cannot be rectified in the subsequent knit fabric production process. Spirality occurs in knitted fabric because all loops tend to distort, thus throwing the fabric wales and courses into an angular relationship other than 90 degree. Garments cut from such fabric show obvious distortion and are worthless. The spirality of the fabric which is knitted to the same loop length from different counts of yarn will be differed. Similarly, from the same count of yarn a fabric made with different weights can show different spirality values. Spirality can be minimized by reducing the residual torque of the yarn or can be eliminated by producing a yarn with no torque. In the previous studies the effect of raw material, yarn spinning technologies, twist liveliness, tightness, number of feeders, washing, relaxation, application of spandex and conditioning were investigated; but in the literature there is not enough study about weight effect on spirality and there is no study about the effect of dyeing on spirality. In this study the fabrics are knitted by cotton yarns which are produced by different technologies and the effect of weight and elastomer on spirality for both gray and dyed fabrics were investigated. The spirality values are determined statistically and experimentally in this chapter.

When knitting is done by using a circular weft knitting machine, there is an inherent spirality as the courses are laid in a continuous helix around the machine. This means that the courses never form a perfect right angle with the wale line. This is unavoidable. The more feeders there are around a machine or conversely, the shorter the course length, the steeper the angle of the helix will be. As this is a feature of circular knitting, this is not considered to be a defect.

However, with some fabrics either as a result of high yarn twist, low tightness factor or poor finishing or perhaps the influence of some other distortion, there is an inherent potential for fabric twisting, skewing or spirality. If the angle of this distortion is small it is tolerable but if this becomes larger, it is cause for concern as the garment becomes unsightly and even uncomfortable to wear. This distortion often develops as the cloth from which the garment is made relaxes as a result of wear or most commonly after washing. The classic outcome of such relaxation is the twisting of the side seams so that they no longer lie straight down the sides but instead twist around the wearer's body so one seam is at the front and the other at the back (Figure 4.1).

Spirality is therefore a measure of quality of weft knitted fabric and whether expressed in mm, percentage, or angle, it should be minimal if the fabric is to be serviceable. For many years, the garment industry has used in-house methods to determine the potential for spirality in knitted fabrics either by measuring the fabric before making or by measuring the garment after making.

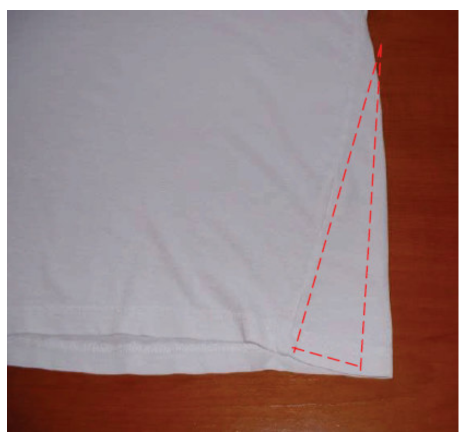


Figure 4.1 Twisting of the side seams

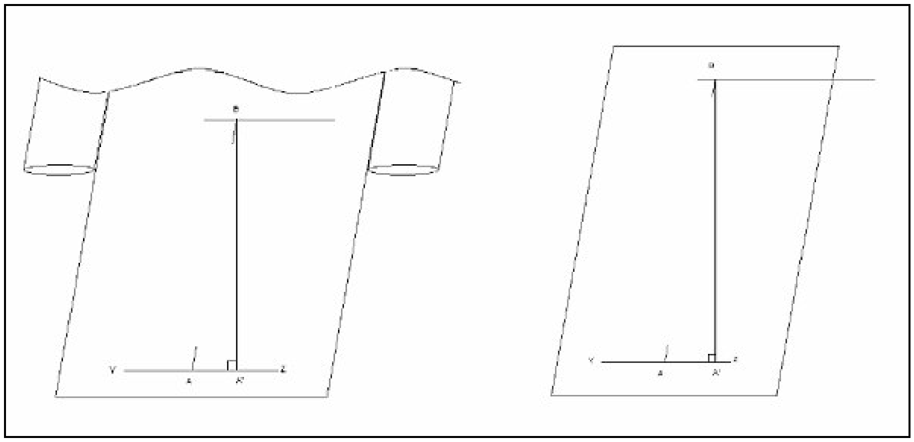


Figure 4.2 Measuring of spirality

In June 2005, the International Standards Organization (ISO) has published a standard in 3 parts (clearly based on AATCC 179:1996 but not identical) to formalize a series of procedures for measuring this property. ISO 16322 Part 2 tackles the assessment of spirality as a result of washing when measured in fabric form. Part 3 of the standard tackles the measurement of the property in garment form. Part 1 calculates the percentage spirality from the angle subtended by the wales to the courses or more precisely the difference between the angle subtended at A in Figure 4.2 and a right angle (90).

Thus if the courses are at 85^o to the wales (instead of 90^o), then the spirality angle is seen as 90^o-85^o =5^o, it then converts this angle to a percentage of 90^o. This percentage is not comparable with the percentages calculated by the other two parts. In Parts 2 and 3 of the standard, the spirality is calculated from triangles as shown below: The diagrams in Figure 4.2 both show the specimen after washing, hence the lack of right angles at the corners. The first is of a garment on which a horizontal base line and a perpendicular at its centre point to point B are drawn before washing. After washing, a new perpendicular is dropped from B to the base line at A' to make the third side of the triangle. The second diagram is of a flat fabric with a similar triangle drawn. The spirality is calculated from the movement A A' as a percentage of either the length AB (Part 2) or A'B (Part 3). AATCC 179 calculates from AB in all cases. The difference in lengths AB and A'B are small for small angles of spirality but may become significant with very large angles of spirality so care is needed to ensure the correct lengths are used in the calculations.

Figure 4.3 Distortion of side seam after laundering

A similar calculation can be done using the side seams of a garment and the movement of the seam away from the perpendicular. It is worth noting that when using the side seam method, the result can only be an approximation because of the distortion as seen in Figure 4.3 caused in the panels and the hemline by higher levels of spirality. It is more precise to use the constructed triangles as shown in Figure 4.2. An example of wavy hemlines and distortion is shown in Figure 4.3 [29].

4.2 MATERIAL

Twenty five different fabrics used in the experimental study part of this study are produced in SANKO Gaziantep. The fabrics are knitted by two different marked knitting machines. All the fabrics are knitted as single jersey by Ne 30/1 cotton yarns. The choice of these fabrics reasons are versatile using area of single jersey fabric as t-shirt, underwear, sportswear and baby clothes, easy and fast production, cheapness and comfort. The production method of yarns which are used to produce these fabrics is basically conventional ring spinning method and also the ring yarns are differentiated as carded ring yarns twisted in S direction, carded ring yarns twisted in Z direction and combed ring yarns. In Table 4.1, fiber properties used to produce combed and carded yarns are given. The characteristics of yarns are given in Table 4.2.

Table 4.1 Fiber properties for sample yarn types

Fiber Properties	Type of Yarn	
	Combed Yarn	Carded Yarn
Micronaire	4.4-5.1	3.8-4.4
Length	30.14 mm	29.94 mm
Strength	34.4 g/tex	33.9 g/tex
Uniformity	84.4	84.0
% 25 Length	29.19 mm	29.59 mm
% 50 Length	15.17 mm	14.22 mm
SFI	4.4	5.0
Humidity	8.5	7.2

Table 4.2 The Characteristics of yarn used for knitted samples

Yarn Characteristics	Ne 30/1 Combed	Ne 30/1 Carded
U%	9.7	11.9
Thin places (±50 % /km)	1	11
Thick places (±50 % /km)	12	128
Neps	23	207
Hairiness	6.6	7.2
Yarn Strength (RKM)	17.05	14.35
Elasticity (%)	3.9	3.8
Twist (T/m)	791	796

By using Monarch machine 12 different fabrics are produced. The effect of elastomer on the spirality is investigated, the fabrics are produced as both with elastomer and without elastomer in two different weight adjustment in Mayer & Cie Relanit machine. After this differentiation 12 different fabrics are then produced. The technical properties of Monarch and Mayer&Cie Relanit machine which is used to produce these fabrics are given in Table 4.3.

In addition to twenty four fabrics a fabric is knitted by using both carded S yarn and carded Z yarn in the same fabric. The characteristics of both carded S and carded Z yarns are same but only the twist direction is different. This type of fabric is known as S-Z in literature. Finally there are thirty three different fabrics. These fabrics are produced from 30/1 Ne cotton with a knitting machines which have 90 feeders and these machines turns with 30 rpm. The technical properties of samples are given in Table 4.4. The samples are numbered and the fabrics are determined according to these numbers.

Table 4.3 The technical properties of Monarch and Mayer&Cie Relanit machine

Technical Properties	**Monarch**	**Mayer&Cie Relanit**
Diameter (inch)	30	30
Gauge (fein)	28	28
Number of Needles	2582	2582
Direction of Machine Rotation	Clock-wise (Z)	Counter Clock-wise (S)
Types of bed	Single bed	Single bed(elastomer applicable)
Number of Feeders	90	90

Table 4.4 Production and technical properties of samples

Samples	Machine	Yarn Type	Fabric Weight (g/m²)		Elastomer Application	Machine Rotation	Number of Wales(1cm)		Number of Courses (1cm)	
			Gray	Dyed			Gray	Dyed	Gray	Dyed
1	Relanit	Combed	107	130	Without elastomer	Counter Clockwise(S)	11	14	17	17
2	Relanit	Carded S	111	127	Without elastomer	Counter Clockwise(S)	13	14	16	14
3	Monarch	Combed	111	139	-----	Clockwise(Z)	12	14	16	18
4	Relanit	Combed	112	131	Without elastomer	Counter Clockwise(S)	12	15	16	19
5	Monarch	Carded S	113	129	-----	Clockwise(Z)	12	15	16	16
6	Relanit	Carded S	114	134	Without elastomer	Counter Clockwise(S)	13	14	16	15
7	Monarch	Carded S-Z	115	147	-----	Clockwise(Z)	15	15	22	17
8	Relanit	Carded Z	116	137	Without elastomer	Counter Clockwise (S)	13	15	17	15

9	Relanit	Carded Z	117	136	Without elastomer	Counter Clockwise (S)	13	14	16	15
10	Monarch	Carded Z	119	130	-----	Clockwise (Z)	12	15	17	15
11	Monarch	Carded S	122	146	-----	Clockwise (Z)	12	15	19	17
12	Monarch	Combed	122	147	-----	Clockwise (Z)	13	16	18	16
13	Monarch	Carded S	130	162	-----	Clockwise (Z)	12	16	21	18
14	Monarch	Carded S	131	155	-----	Clockwise (Z)	12	16	20	18
15	Monarch	Combed	132	159	-----	Clockwise (Z)	13	15	21	15
16	Monarch	Combed	132	157	-----	Clockwise (Z)	12	15	20	18
17	Monarch	Carded Z	134	162	-----	Clockwise (Z)	12	16	22	20
18	Monarch	Carded Z	136	150	-----	Clockwise (Z)	12	17	22	18
19	Monarch	Carded Z	142	154	-----	Clockwise (Z)	12	16	22	17
20	Relanit	Carded S	153	194	With elastomer	Counter Clockwise (S)	15	16	13	19

21	Relanit	Carded S	159	207	With elastomer	Counter Clockwise (S)	14	16	18	19
22	Relanit	Combed	164	197	With elastomer	Counter Clockwise (S)	15	16	18	19
23	Relanit	Carded Z	165	188	With elastomer	Counter Clockwise (S)	14	16	18	15
24	Relanit	Carded Z	167	214	With elastomer	Counter Clockwise (S)	14	16	19	19
25	Relanit	Combed	167	194	With elastomer	Counter Clockwise (S)	14	16	18	18

The twenty five fabrics are dyed to investigate the dying effect on the spirality. Dying process is done in SANKO dyeing mill Gaziantep. The dying recipe is given in Table 4.5.

After dying the number of samples is 25*2=50.

The properties; fabric weight in square meter, number of stitches per unit length (1 cm) and spirality after washing and drying were determined via the equipments and devices in the laboratories of Textile Engineering Department of Gaziantep University in accordance with the standards. The apparatus and devices used in the experimental studies are given below:

1. Sensitive scale and specimen cutter for fabric weight measurement
2. Magnifier
3. Automatic washing machine
4. Automatic tumble dryer
5. Standard reference detergent
6. Perforated table
7. Marker to mark wale and course on specimen
8. Protractor to measure angle of spirality

Table 4.5 Relevant Recipes for sample fabric

Cooking Recipe		**Dyeing Recipe**		**Washing Recipe**	
Product	**Amount**	**Product**	**Amount**	**Product**	**Amount**
Cottoclarin Ok	0.6 g/l	Syn Red Shf-Gd	0.008 %	Acetic Acid % 80	0.5 g/l
Mollan 129	0.5 g/l	Syn Blau Shf-Brn	0.006 %	Locanit Sw	0.2 g/l
Caustic	1 g/l	Mollan 129	0.5 g/l	Enbrite Cn-1	0.35 %
Hydrogen Peroxide	1 g/l	Imacol C-2G	0.3 g/l	Acetic Acid % 80	0.5 g/l
Baystabil Db-T	0.5 g/l	Sodium Sulfate	30 g/l	Belfasin Lx	2.5 g/l
Gemperaz Ahp 6	0.4 g/l	Sodium Carbonate	10 g/l	Belsoft Tv	2.5 g/l
Acetic Acid	0.5 g/l				

The standards, which were followed for this experimental studies are given above related topics.

4.2 METHOD

4.2.1. The Determination Method of Fabric Weight

Fabric weight is determined according to TSE EN 12127 April 1999; "Textiles-Fabrics-Determination of mass per unit area using small samples" The specimens are cut as 10 cm² from five different places on same sample. Then these specimens are weighted by sensitive scale and the average of five weights is calculated. This value is multiplied by 100 to find the weight of fabric for 1m². The calculated weights of samples are given in In Table 4.4 [27].

4.2.2 The Determination Method of Fabric Wales and Courses

The number of wales and courses are determined according to TSE EN 14971 July 2006 "Textiles-Knitted Fabrics-Determination of number of stitches per unit length and unit area." By using a 1 cm magnifier the number of wales and the number of courses were counted. This counting was done in five different areas in a specimen. The average of five results was calculated is seen in Table 4.4 [28].

4.2.3 Relaxation Processes

4.2.3.1 Dry relaxation

Prior to marking, the samples were pre-conditioned and than conditioned test specimens as directed in ASTM Practice D 1776, Conditioning Textiles for Testing. Each specimen was conditioned at least 4 h in an atmosphere of 21 ± 1^{o} C ($70 \pm 2\ ^{o}$F) and $65 \pm 2\%$ RH by laying each specimen separately on a screen or perforated shelf of a conditioning rack [30].

4.2.3.2 Laundering

The samples were laundered according to AATCC Test Method 179 (1996), *Skewness Change in Fabric and Garment Twist Resulting from Automatic home Laundering*. Preferred washing machine is home type and programmer is B; washing process is 2 hours and 15 minutes and the temperature is 60^{o} C. Washed samples are dried by a tumble dryer for 70 minutes on 70º C. These laundering properties are chosen because the single jersey fabrics are generally used as under clothes and many people wash and dry these clothes under these laundering conditions. It is important to investigate the home laundering effect on the spirality [30].

4.2.4 Determination the Angle of Spirality

Spirality is determined according to IWS 276 test standard method. This method is intended to measure the angle of spirality in the structure of a plain knitted garment following relaxation in water. According to this method 5 different places are chosen for each sample, first a wale is marked by a pen and the course linked wale is then marked. By using a protractor the angle different from the normal of the wale is measured [31]. In this experimental study spirality of single jersey knitted fabrics is investigated as a function of yarn production technology, yarn twist direction, fabric weight, dyeing and elastomer application.

4.3 COMMERCIAL ASPECTS

In this experimental study spirality of the fabrics are measured in two ways as commercial and scientific aspect. All the results were assessed according to scientific aspects but on the other hand commercial aspects must be kept in mind. The influence of spirality on garments has vast importance. So distortion of garments is measured instead of degree of spirality in commercial mills. In Sanko Holding the samples were knitted and dyed, to determine this distortion by measuring the displacement of side seams after laundering.

In this mill, first the fabrics were pre-conditioned and than conditioned as directed in ASTM Practice D 1776, *Conditioning Textiles for Testing*. Each specimen was conditioned at least 4 h in an atmosphere of 21 ± 1 ^{o} C (70 ± 2 ^{o}F) and 65 ± 2% RH by laying each specimen separately on a screen or perforated shelf of a conditioning rack. Than the fabrics were cut in 1 m length and sewn on both sides. The sewn fabrics were laundered according to AATCC Test Method 179 (1996), *Skewness Change in Fabric and Garment Twist Resulting from Automatic home Laundering.* The samples were spreaded flat on a smooth horizontal after tumble drying. According to the customer's desire, the seam slippage from both sides were measured (Figure 4.4). The seam displacement values for gray and dyed samples are given in Table 4.6.

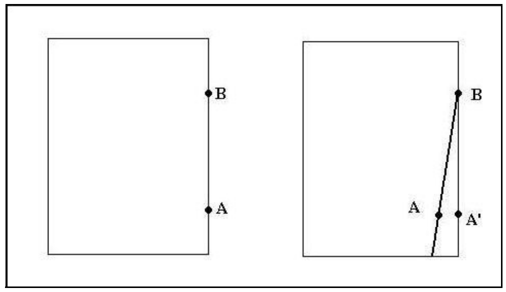


Figure 4.4 The displacement of side seam of the sewn knitted fabrics after washing

Table 4.6 Spirality and seam displacement values of both gray and dyed samples

Samples	Spirality (degree)		Seam Displacement (cm)	
	Gray	Dyed	Gray	Dyed
1	13,6	4,6	19,5	3,3
2	8,2	1,6	7	0,9
3	12,2	3,8	19,9	2,4
4	11,4	7	22,5	2,4
5	6,6	2,8	11,5	0,9
6	8,4	5,2	11	0,8
7	0	0,8	0,5	0
8	11	4,6	14,8	8,9
9	12,4	4,8	22,3	9,3
10	13,8	8	14,6	5,6
11	5,8	3,2	9,5	0,7
12	12,8	5,8	12,5	3,9
13	2,8	3	6,3	0,9
14	1,4	2,6	4,6	0,4
15	8,8	4,8	10,1	1,8
16	8	3,6	6,3	2,5
17	2,6	4	9,9	4,6
18	10,2	2,6	12,1	1,2
19	6,4	2,2	4,1	5,1
20	8,2	4,8	8,1	0,5
21	7,2	4	9,6	1,2
22	5,2	2,6	22,8	4,8
23	6	3,2	9	5,5
24	5,6	3,8	9,5	4,9
25	7,8	1	11,5	3

4.4. RESULTS

4.4.1 The Effect of Fabric Weight on Spirality According to Yarn Producing Technology

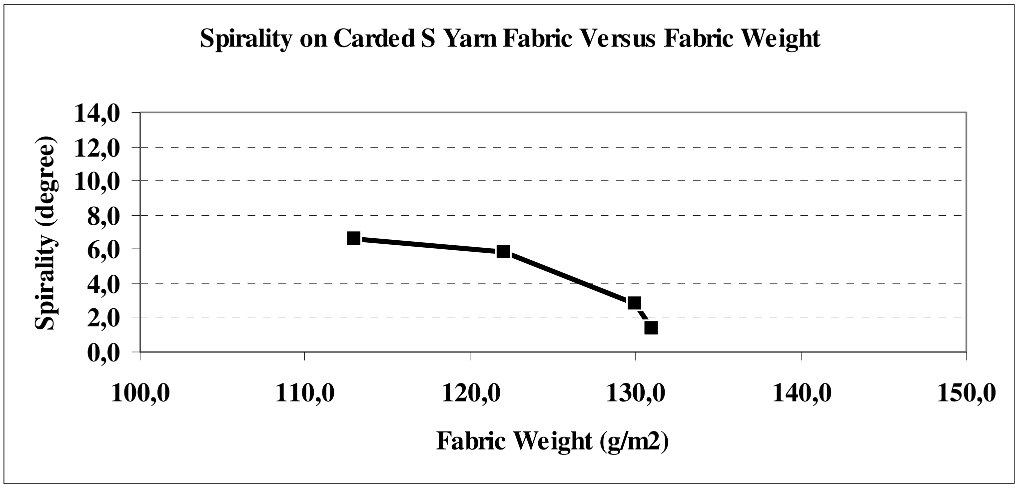


Figure 4.5 Spirality of carded S yarn fabrics versus fabric weight (Machine rotates Z direction)

Figure 4.5 illustrates the spirality values of carded S yarn fabrics versus four different fabric weights. It is seen from the Figure that increasing the fabric weight result in decreasing spirality values for carded S yarn fabrics. The highest spirality value is 6.6 for 113 g/m² fabric weight while the lowest spirality value is 1.4 for 131 g/m² fabric weight.

According to ANOVA results, the effect of fabric weight on spirality was found to be significant ($p \leq 0.01$) at 1 % significance level.

Figure 4.6 and Figure 4.7 show the effect of fabric weight on spirality for carded Z and combed yarn fabrics respectively. The common feature of these graphical representations is higher levels of spirality than other yarn type fabrics. For carded Z yarn fabrics increasing the fabric weight from 119 g/m² to 142 g/m² cause the spirality to decrease from 13.8 to 6.4. On the other hand for combed yarn fabrics the lowest spirality value is 8 versus 133 g/m² while the highest spirality value is 12.8 versus 122 g/m². It is clear from the relevant Figures with carded Z, carded S and combed yarn fabrics the lowest spirality values versus fabric weights belong to carded S yarn fabrics.

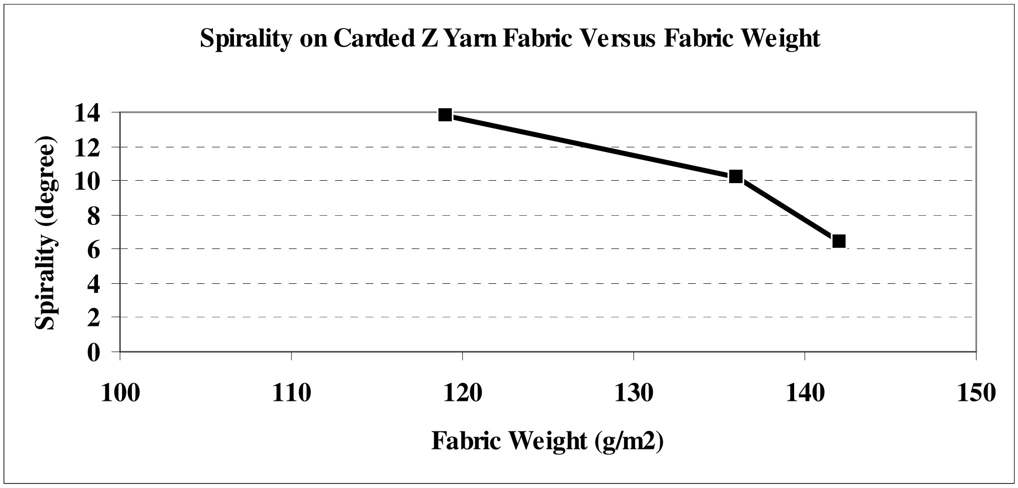


Figure 4.6 Spirality of carded Z yarn fabrics versus fabric weight (Machine rotates Z direction)

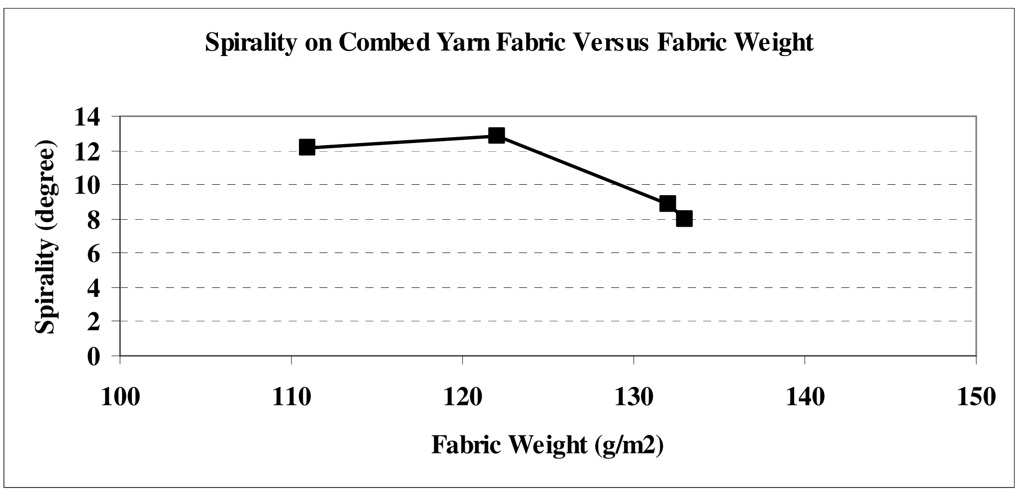


Figure 4.7 Spirality of combed yarn fabrics versus fabric weight (Machine rotates Z direction)

This situation is due to relationship between yarn twist direction and the direction of machine rotation; because these yarns are knitted on Monarch machine which rotates in the opposite of twist direction.

4.4.2 The Effect of Dyed Fabric Weight on Spirality According to Yarn Producing Technology

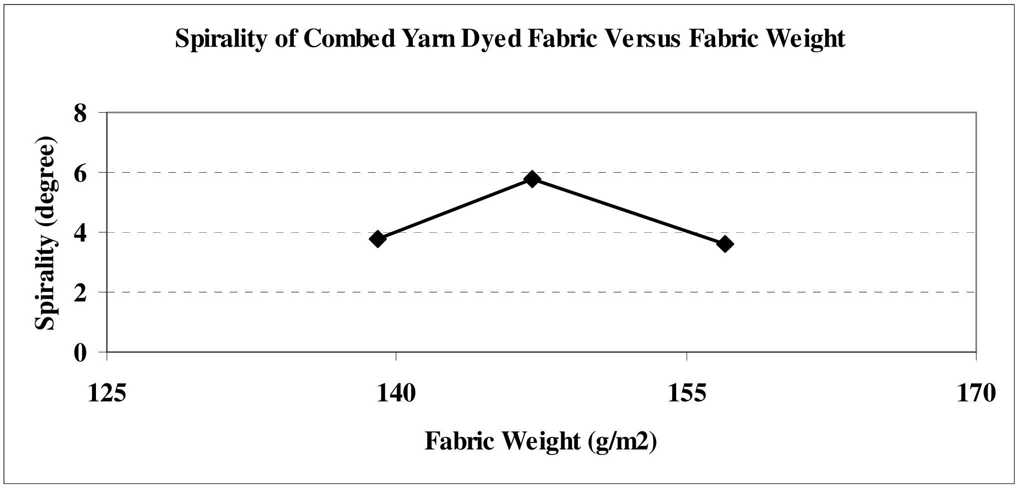


Figure 4.8 Spirality of combed yarn dyed fabrics versus fabric weight (Machine rotates Z direction)

If the Figure 4.8 is examined, it is seen that there is no regular effect. By increasing weight of fabric spirality value increases for few weights and decreases for other few weights. To investigate statistical effect of weight, ANOVA tests are performed. The results are observed, it can be seen that the effect of fabric weight on spirality with dyed combed fabrics is not significant ($p \leq 0.05$) at 5% significance level. There is still lack of information in the literature that in dyed fabrics the effect of fabric weight on spirality. According to Tukey Tables the fabrics are in the same group. It means weight is not important on dyed combed yarn fabrics in SPSS.

On the other hand spirality results of both gray fabrics and dyed fabrics show that dyeing decreases spirality about half. If the spirality values are compared on the same fabric weight; on gray fabric the spirality value is 8 versus 132 g/m² and on dyed fabric the spirality value is 3.8 versus 139 g/m². It is clear from the statistical data and experimental evaluations that dyeing affect spirality more than weight of fabric on combed yarns.

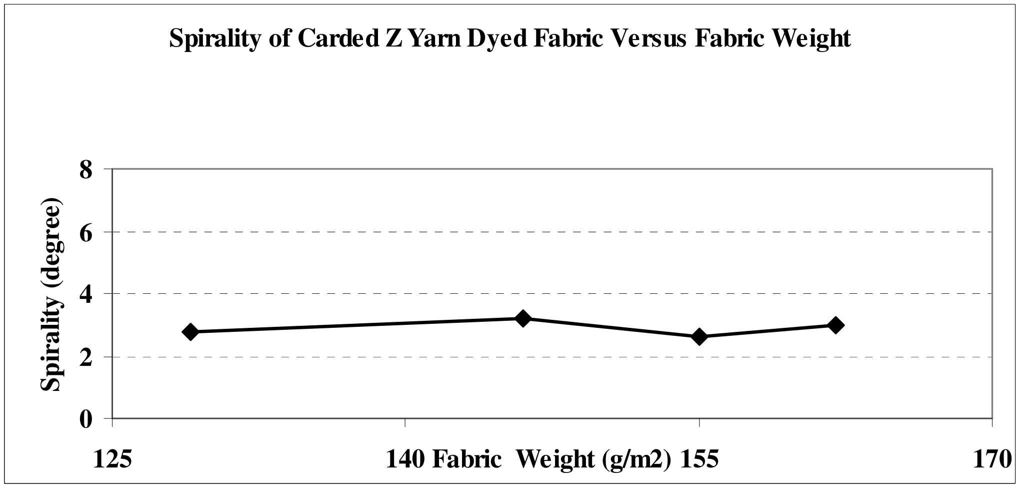


Figure 4.9 Spirality of carded Z yarn dyed fabrics versus fabric weight (Machine rotates Z direction)

Figure 4.9 illustrates the effect of weight on spirality with carded Z yarns. The diagram demonstrates the effect of weight clearly. At the same time the results of ANOVA show that the effect of weight on spirality is significant ($p \leq 0.01$) at 1% significance level. Again when the results of dyed fabrics are compared with the results of gray fabrics, it is evident that dyeing process makes the spirality value decreases. And moreover, the highest spirality value is 8 versus 130 g/m² on dyed fabrics while the highest spirality value was 13.8 versus 119 g/m². If the effects on results are not clear; by examining the fabrics which weights are closed the spirality values can be compared. For dyed fabrics the fabric weight is 130 g/m²and spirality is 8; but for gray fabrics spirality is 10.2 versus weight are 136g/m². So it is clear that dyeing again decreases spirality on carded Z yarn fabrics.

Figure 4.10 shows the carded S yarn fabrics' spirality versus increasing fabric weight. By examining the diagram it is seen that there is no relationship between fabric weight and spirality with dyed fabrics. At the same time ANOVA tests were applied to the spirality values of carded S yarn fabrics. The results show that it is not significant ($p \leq 0.05$) at 5 % significant level. However, in gray fabrics, the spirality decreases while fabric weight increases. The only result is obtained from data is spirality decreases half after dyeing process.

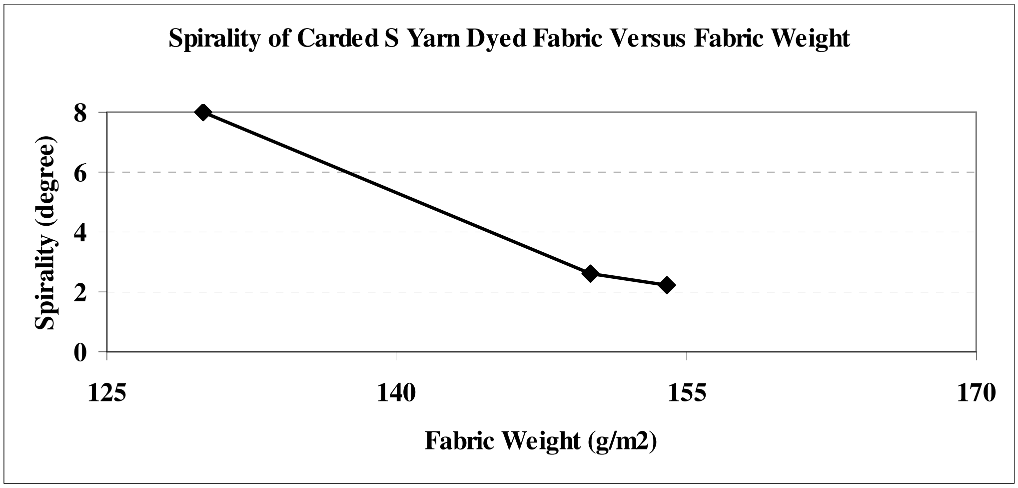


Figure 4.10 Spirality of carded S yarn dyed fabrics versus fabric weight (Machine rotates Z direction)

After each yarn production technology was tested on the effect of weight on spirality, general ANOVA test as applied all the dyed fabrics. The results are significant ($p \leq 0.01$) at 1 % significance level.

4.4.3 The Effect of Elastomer on Spirality for both Gray and Dyed Fabrics According to Yarn Producing Technology

A number of sources in the literature note that spirality decreases by the application of elastomer. The application is investigated both for gray fabrics and dyed fabrics in this study. And the difference between yarn production technologies is observed. Furthermore by knitting machine from the fabrics represented before the effect of twist direction is wanted to show. During the tests of spirality there is a skewness in the fabrics that is related with spirality but not same, the wales are turn with the turning of courses. But there is no skewness in the fabrics so spirality results are high in the fabrics with elastomer.

This is particularly evident in Figure 4.11 which deals with spirality decreases by elastomer application with all yarn production technologies. To investigate the effect of elastomer one way ANOVA test was done. There is a significant importance ($p \leq 0.01$) at 1% significant level. If the diagram is observed, whether there is an evident difference between yarn production technologies or not.

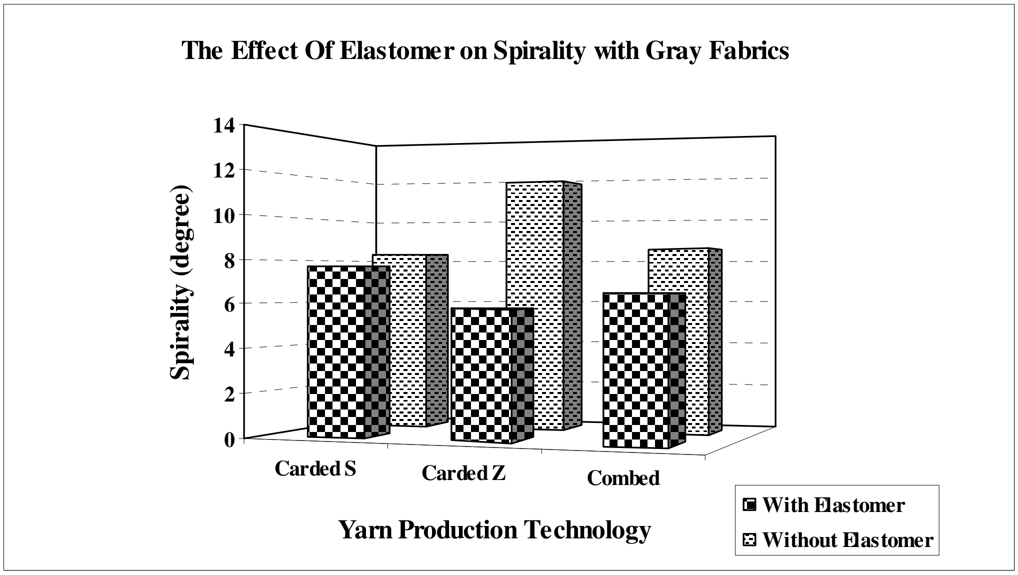


Figure 4.11 Spirality changing of gray fabrics with elastomer application versus yarn production technologies according (Machine rotates S direction)

In addition combed yarns knitted without elastomer has a spirality value as 8.5 while the same yarns knitted with elastomer has a spirality value as 6.5. At last carded S yarn fabrics are investigated and it is seen the spirality of fabrics without elastomer is 8.3 while the spirality of fabrics with elastomer is 7.7. There is evidence that the elastomer application has an influence on the spirality. While comparing the data it should be observed that a yarn which has more spirality by fabrics knitted without elastomer has less spirality by fabrics knitted with elastomer. It means the highest spirality results in the lowest spirality when elastomer is applied to the fabrics. Accordingly it can be concluded that the spirality values of fabrics with elastomer are Carded Z yarn fabrics < Combed yarn fabrics < Carded S yarn fabrics.

Figure 4.12 illustrates the diagram of elastomer effect on spirality with dyed fabrics versus different yarn production technologies. If the spirality values are compared the result is seen as;

Combed yarn fabrics < Carded Z yarn fabrics < Carded S yarn fabrics knitted with elastomer. The results are similar to results of gray fabrics. It means there is a correlation between spirality values of fabrics with elastomer and fabrics without elastomer versus yarn production technologies.

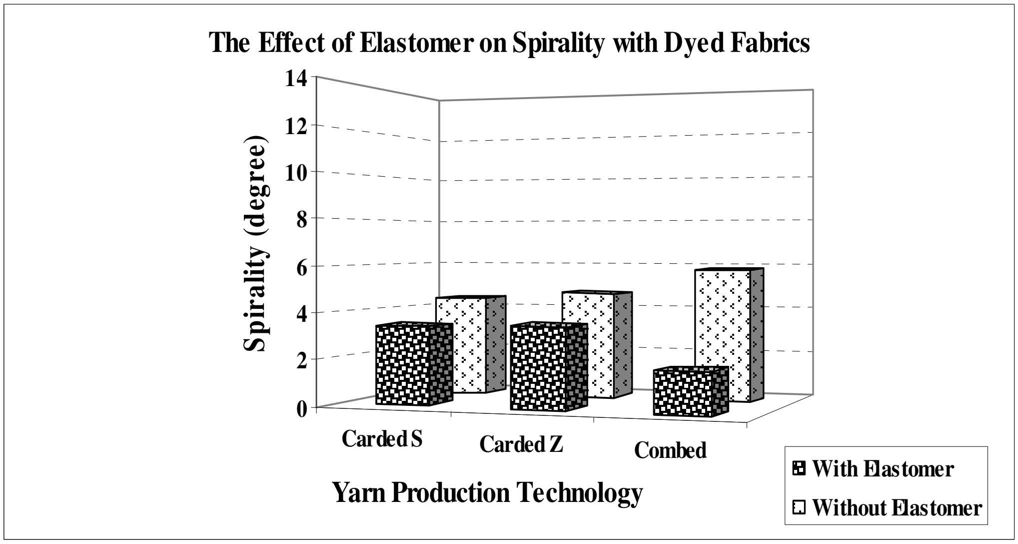


Figure 4.12 Spirality changing of gray fabrics with elastomer application versus yarn production technologies (Machine rotates S direction)

The results of our ANOVA tests show that there is a significant effect ($p \leq 0.01$) at 1% significance level. If the results of both gray fabrics and dyed fabrics are examined in carded S yarn fabrics the spirality values are closed to each other. This is not surprising since Relanit machine rotates clockwise direction like carded S yarn are produced with S twist (clockwise) while carded Z and combed yarns are produced with Z twist (counter-clockwise). So carded S yarn fabrics have the highest spirality values. Furthermore a correlation is made on dyed fabrics to show the effect of elastomer application on spirality. According to statistical correlation analysis the results of dyed fabrics are insignificant.

4.4.1 The Effect of Yarn Twist on Spirality for both Gray and Dyed Fabrics According to Yarn Twist Direction

Figure 4.13 implies the effect of yarn twist direction on spirality with gray fabrics and dyed fabrics. The samples were knitted by using Monarch machine. Represented machine's rotation counter-clockwise direction; to investigate the effect of yarn twist direction, carded S yarn fabrics and carded Z yarn fabrics are produced and tested.

In addition to this, the fabrics are dyed and again the effect of yarn twist direction is examined for dyed fabrics. From the given diagram, it is seen that the lowest spirality values belong to carded S yarn fabrics and the highest values belong to carded Z yarn fabrics. At the same time, ANOVA tests are applied to the spirality values for either gray fabrics or dyed fabrics. Results of two group of specimen are significant ($p \leq 0.01$) at 1% significance level.

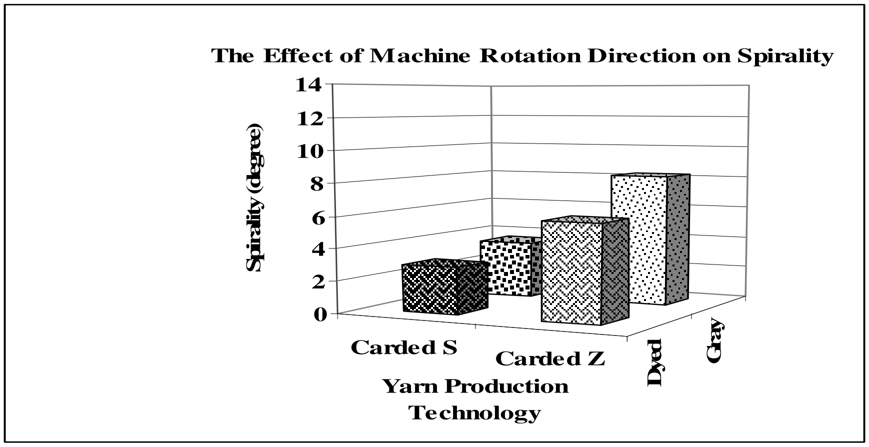


Figure 4.13 Spirality of carded S and carded Z yarns for both gray and dyed fabrics versus yarn twist direction (Machine rotates Z direction)

CHAPTER 5

CONCLUSION and DISCUSSION

5.1 CONCLUSION

Rising popularity of knitted fabrics brings some serious problems together. The difficulty of retaining the dimensional stability fabrics is one of the most important problems. Spirality is defined as the distortion o 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 with one needle system, the wales and the courses are not perpendicular to each other as required but skew to the right or left, forming an angle of spirality with the perpendicular.

The main aim of this work was to systematically investigate the effect of yarn production technologies, yarn twist direction, fabric weight, elastomer application and dyeing on the spirality of knitted fabrics. In this study, the parameters are investigated for plain fabrics made from cotton ring spun yarns.

The results show that the weight of fabric is very important for all yarn production technologies for gray fabrics. The data, graphics and statistical analysis of spirality values showed that increasing of fabric weight decreases spirality. But the decreasing is not the same reverse proportion for all yarn types. When the results were investigated it was seen that the lowest spirality values were belonged to carded S yarn fabric. And the highest spirality values belong to carded Z yarn fabric. We expect to find closed spirality values for carded Z yarn fabrics and combed yarn fabrics and our result confirmed us. Because the twist directions of both were the same.

It is apparent from the results that dyeing process decreases spirality. The yarns have torsion and this torsion results in spirality on a knitted fabric. If the torsion decreases it means the spirality decreases too. Dyeing process decreases this torsion so the spirality values of dyed fabrics were less than spirality of gray fabrics. This decreasing was up to half of gray fabrics' spirality values. When the effect of fabric weight on dyed fabrics was examined there was no significant effect on spirality. The reason may be again torsion. There is no direct proportion between the decreasing values of spirality. However there is still lack of information in the literature that in dyed fabrics the effect of fabric weight on spirality. It means that the effect of fabric weight with dyed fabrics is not significant.

According to the results, twist direction is another important parameter on spirality. Because machine rotation have an effect on yarn tensional force that increases spirality. To investigate the effect of yarn twist direction, carded S yarn fabrics and carded Z yarn fabrics were produced and tested. In addition to this, the fabrics are dyed and again the effect of yarn twist direction was examined for dyed fabrics. When the results, graphics and statistical analyses were examined it was concluded that carded S yarn fabrics' spirality values were less than carded Z yarn fabrics' spirality values. Because; the machine rotation direction and twist direction of carded S yarn are opposite to each other.

It is apparent from the results that to spirality decreases by dyeing process; application of elastomer is another preferable way. According to the results of both gray and dyed fabrics' spirality values, there is evidence that the elastomer application had an influence on the spirality. While comparing the data it should be observed that a yarn which has more spirality by fabrics knitted without elastomer has less spirality by fabrics knitted with elastomer. It means the highest spirality results in the lowest spirality when elastomer is applied to the fabrics.

To sum up the results of this study are;

- Carded S yarn gives lowest spirality values.
- By the increasing of fabric weight the spirality values decrease.
- Dyed fabrics imply lower spirality values.
- By the application of elastomer spirality decreases.
- If the twist direction of yarn and machine rotation direction are different; it results in lowest spirality.

5.2 DISCUSSION

In the previous studies there are many approaches to minimize spirality, but to my mind there is no definite spirality description and no certain method to measure spirality. According to the literature there is a 90^o angle between course and wale. Spirality means the changing of this angle from 90^o. It is clear that by using this definition spirality is determined by the angle method. However in the literature some were described spirality as the drop effect or course skew in the single jersey fabrics is due to the helical disposition of the courses. According to this description spirality means as skewness; and spirality is determined by measuring this skewness. Other sources describe spirality as the seam displacement. There was evidence that the fabric which has a spirality fault deforms. But this deformation interception between angle of spirality, skewness %, seam displacement are not directly proportional to each other.

There is also lack of information that the measuring method of angle or skewness. According to IWS 276 standard this angle is measured by a protractor, in another study the angle of spirality is measured by using the following formula:

Degree of spirality θ= tan-1(d/l)

Where, d=displacement of the course from a normal line to the wales of the fabric measured at a distance 'l' from the identified wale line.

In some studies skewness is measured by determining the seam displacements on garment after washing and according to others a square is drawn on sample than after washing the distance between diagonal sides of square is equal to the skewness of the fabric.

Moreover, in the previous studies angle of spirality was measured like in Figure 3.6 "Angle between course and wale" and this method was used in this study. According to the this figure wales incline to the right and θ is measured by assuming the courses are straight; but as seen from the figure there is also an inclination of courses. This figure proves that angle of spirality method measures the inclination of wales but skewness change method measures the deformation of fabric depend on the inclination of courses. So it means to measure spirality angle of spirality method gives more reliable results. Because in our samples it is seen that that on some fabrics spirality values were low while fabric has a clear deformation and at the same time with the application of elastomer fabrics seem steady while their spirality values are high.

At the same time in this study the importance of spirality for commercial aspects was thought and in SANKO mills that the samples were produced the spirality was measured according to their method. As mentioned before spirality is measured by seam displacement method in this mill. Figure 4.4 shows the displacement of side seams of the sewn knitted fabrics after washing.

The results are given in Table 4.7 and it is seen that there is no direct proportion between seam displacements and angle of spirality.

5.3 RECOMMENDATIONS

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

1) To obtain more precise yarn feeding into the fabrics LFA must be preferred instead of fabric weight adjustment on circular knitting machines.

2) These tests may also be done on fabrics which are produced by the yarns of new spinning systems like rotor, friction, air-jet, and air-vortex.

3) It could be useful that during the experimental studies use of fabrics which are undertaken finishing process and compare the results.

4) It could be useful that use of different raw materials and properties like (polyester, viscose and wool) and determine dimensional changes.

5) To determine the effect of laundering process, different temperature and different laundering time may be applied.

6) There are many methods to measure spirality, all these methods may be used and these results may be compared. And the relation ship may be determined between them.

7) Previous works pointed out that knitted fabrics with dyed yarns have lower spirality. This situation must be investigated in details to optimize the cost and fabric spirality.

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