ÖZET

TEK İĞNE YATAKLI YUVARLAK ÖRME KUMAŞLARIN PERFORMANSI ÜZERİNDE ASKININ ETKİLERİ

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Atkılı örme kumaşlar birbirleriyle bağlantı yapan halkalardan oluşur. Her bir halka ilmek olarak isimlendirilir. Yuvarlak örme kumaşlar esnek , yumuşak tutumlu ve dökümlü yapısıyla bilinir ve çoğunlukla iç giyim, yazlık ve kışlık spor giyimde, dış giyim (iç çamaşırı, tişört, lakos, eşofman v.s.) kullanılır.

Süprem, ribana, interlok ve haroşa olmak üzere 4 ana atkı örme kumaş tipleri vardır. Lakos, iki veya üç iplik, selanik v.b. farklı kumaş desenleri standart ilmekle farklı ilmeklerin birlikte ana kumaş yapılarında kullanılmasıyla elde edilir. Farklı kumaş desenleri kumaş yapısını değiştirmekte ve bu kumaşların birbirlerinden farklı davranışlar sergilemesine yol açmaktadır. Bu sebeple kumaş deseni sadece bir görünüm özelliği olarak değerlendirilmemeli aynı zamanda önemli bir yapısal parametre olarak göz önüne alınmalıdır.

Bu çalışmada, kumaş ağırlığı, kumaş kalınlığı, patlama mukavemeti, aşınma dayanımı, boncuklaşma dayanımı, yıkama sonrası çekmezlik, may dönmesi gibi kumaş özellikleri üzerinde askının etkileri incelenmiştir. Test sonuçlarına ve istatistiksel analizlere göre askı ilmeğinin bu özellikler üzerinde önemli etkiler gösterdiği gözlenmiştir.

Anahtar kelimeler: Askı ilmeği, süprem, boyutsal stabilite, patlama mukavemeti, aşınma dayanımı, boncuklaşma dayanımı, kumaş kalınlığı, may dönmesi.

ABSTRACT

INFLUENCES OF TUCK STITCH ON THE PERFORMANCE OF THE CIRCULAR KNITTED FABRICS WITH SINGLE BED

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The weft knitted fabrics are formed by series of loops, intermeshings in rows. Each loop is called as a stitch. The circular knitted fabrics are characterized by a flexible, soft handle and drapes structure and mostly used for underwear, summer and winter sportswear, outer-wear (t-shirt, lacostes, sweat shirts etc.)

There are 4 main weft knitted fabrics as plain knit (single jersey) , ribana, interlock and purl. Different fabric types as lacoste, fleece, cardigan etc. are obtained as using standard loop and different loops together in main weft knitted fabrics. The tuck stitch is one of different loops. Different fabric types differentiate the structure of fabrics and these different structural properties of fabrics will cause the fabrics to behave differently from each other. In this point of view fabric pattern must be evaluated not only as an appearance property but also a very important structure parameter indeed.

In this thesis work the influence of tuck stitch on fabric properties such as fabric weight, fabric thickness, bursting strength, abrasion resistance, pilling resistance, dimensional stability, spirality properties for knitted fabrics were investigated. According to the test results and the statistical analysis it is observed that the tuck stitch has an important effect on these mentioned properties.

Key words: tuck stitch, single jersey, dimensional stability, bursting strength, abrasion resistance, pilling resistance, fabric thickness, spirality,

TABLE OF CONTENTS

CHAPTER 3

MATERIALS AND METHODS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1. Introduction

Textile materials and ready made clothes are generally used for protecting from environmental conditions, making life easy, covering body, and 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 man-made 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.

Knitted fabrics have a very wide range of applications, starting from underwear and everyday clothing, especially t-shirt, sweat-shirt etc. sportwears decorative and furniture fabrics, up to technical textiles. Such a wide range of application means that during their lifetime fabrics undergo actions from different forces and strains depending on their destination and working conditions. They can be stretched in many directions for example sportwears, bursted for example socks or compressed for example rigid interlining. In most of the mentioned cases fabrics are used at least a few times, and sometimes the number of work cycles can total many thousands of repetitions. In each work cycle, the total deformations are significant, and users expect that, after removing the forces, the fabric will return its primary state [1].

Fabric design is a major component of the field of textile engineering. In many cases the desired fabric properties are known or specified by the end user, but the yarn and needed to obtain these properties are not known. Furthermore, the properties of the yarn do not directly correlate the fabric behavior. For example, the strength of a fabric depends not only on the strength of the constituent yarns but also on the yarn structure as influenced by the spinning system, yarn bending behavior, fabric geometry, knitting conditions, fabric finishing treatments and many other parameters [1].

A knitted structure is produced by a knitting machine. Knitting is performed briefly as the following: interlooping consist 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 into two groups: “warp knitting” and “weft knitting”. Weft knitted fabrics are the most commonly used type. There are three main structures for weft knits; RL (s.jersey-plain knit, lacoste, fleecy etc.), RR (ribana, interlock, cardigan etc.) and LL (purl) structures. In our daily life, plain knitted structures are used frequently.

Single jersey is the plain RL knit fabric knit on single plate circular knitting machine. It contains only loops in the knit repeat has no tuck, miss knit [2]. S.jersey is a fairly elastic fabric in which face and reverse side are different in appearance and which tends to curl [3]. Its production rate is very high because of the stitch simplicity, and production costs are relatively inexpensive because of the machine simplicity [4]. Ajgaonkar [5] described that this fabric is unbalanced because it is knitted on one set of needles. Therefore the loops tend to curl towards the front at the top and bottom ends and towards back at the sides, which makes curling difficult to control. Spirality and bias are common problems in single jersey due to its inherent structural imbalance [6]. Hatch [7] stated that single jersey fabrics have good crosswise and lengthwise elongation, and the degree of elastic recovery varies with the fiber content and yarn structure. The fabric properties and parameters of a jersey structure are also dependent on the loop length [5]. Jersey fabrics are commonly used in the production of hosiery, socks, t-shirts, and underwear.

Different fabric types as lacoste, fleece, cardigan etc. are obtained by using standard and different loops together in the main weft knitted fabrics. The tuck stitch is one of the different loops.

The tuck stitch is formed, as suggested by its name, when the yarn is tucked into the structure by the needle, instead of being formed into a loop. The stretched deformed loop originated as a normal knitted loop which was held by the tucking needle while the other needles knitted an additional course.

The tuck stitch is usually used in fabric patterning, insertion of problematic yarns, shortening of jacquard floats and garment marking. Also, the tuck stitch has important influences on fabric properties. It increases fabric weight, thickness and width and provides the fabrics to become more porous than the other fabrics [8].

1.2. Previous Works

Many researchers have investigated the influence of raw material, yarn production technology, yarn twist, knitting production technology, main knitting fabric types, and chemical treatments on knitted fabric properties such as abrasion resistance, pilling resistance, dimensional stability, spirality properties. Although there are a lot of studies about lacoste and pique type fabrics, these studies are inadequate to determine effect of tuck stitches on fabric performance. Because, the tuck stitch can be in very different needles in fabric. As a result of this, fabrics with tuck stitches are solely not considered as lacoste fabrics. So, previous works are not a good guideline for this study. However, a few studies are found on the influence of the tuck stitch on lacoste and pique fabric properties in the available literature given in below.

Bayazıt [9] studied dimensional and physical properties of various single pique fabrics. The course and wale spacing, thickness, air permeability, weigth, abrasion resistance properties were investigated. Five different types of fabrics were tested for this purpose. One of them was single jersey having no the tuck stitch, the others were lacoste type fabrics having tuck stitch. The fabrics were knitted from Ne 18/1 and Ne 20/1 OE-Rotor 100% cotton yarns. Knitting was performed on a Monarch circular knitting machine which has a positive yarn feeding system, at three different tightness factor values (K) as 12,15 and 17. Two different relaxation procedures as dry and full were applied on samples. No chemical treatment was applied to fabrics before tests. For course-spacing results; course spacing increases, while the K value decreases (loop length rises) for every kind of fabric. Course-spacing decreases, while relaxation progresses. For wale-spacing results; the wale-spacing values of single jersey are lesser than the others having the tuck stitch. It was obviously observed that the tucks have an effect on wale-spacing as causing on increase in it. For fabric thickness results; it was observed that tuck causes an increase in the fabric thickness. For air permeability results; it is observed that an increase in the tightness of the fabric or a progress in relaxation causes an important decrease in air permeability and the air permeability of single jersey fabrics is lesser than the others because of the tucks have a structure that helps the air pass through. For fabric weight results; it is observed that the difference in the knitting structure does not affect fabric weight during dry relaxation, but as relaxation progresses, a significant increase in fabric weight occurs because of the shrinkage of the fabric. For abrasion resistance results; it is observed that as relaxation progresses, an important decrease in abrasion resistance values of every sample and that single jersey fabric has the lowest abrasion resistance value.

Kaya [10]mentioned that performances of single jersey and lacoste fabric in a part of her thesis. The fabrics were knitted from Ne 30/1 combed and carded 100% cotton yarns on a Mayer circular knitting machine. The fabric tests which were dimensional stability, skewness, pilling resistance, bursting strength were made as washed and unwashed. For dimensional stability results; it was observed that shrinkage of lacoste in widthwise direction was quite lower than single jersey, but, shrinkage of single jersey in lengthwise direction was quite lower than lacoste. For pilling results; it was observed that as pilling grade of single jersey was 2-3, pilling grade of lacoste was 4 in unwashed fabrics, pilling grade of single jersey was 3, and pilling grade of lacoste was 4-5 in washed fabrics. For skewness results; it was observed that skewness of lacoste was less than single jersey's because single jersey was more unbalanced. For bursting strength results; it was observed that bursting strength of lacoste was lesser than single jersey because lacoste had porosity knitting structure. And it was observed that there was not an important difference between unwashed and washed fabrics in bursting strength.

Onal [11] studied about effect of fabric characteristics and laundering to shrinkage of weft knitted fabrics. In his study, he decided that knit type and fabric tightness greatly influence fabric shrinkage. While length shrinkage is more than width shrinkage for pique fabric, the tendency is reversed for plain and fleecy knits. There is a reverse proportion between fabric tightness and direction of the fabric dimensional changes. Yarn type and fiber percentage significantly affected knitted fabric dimensional stability.

Some researchers like Gravas et al [12] and Ertugrul & Ucar [13] studied about the prediction of the shrinkage of the knitted fabrics. Most of the problems encountered in the knitting industry are concerned with variations in dimensions which directly affects the fabric weight.

Candan et al. [14] stated that the knits from ring spun yarn posses more bursting strength than that of open end spun yarn.

Ertugrul and Nuray [15] reported that fabric weight, yarn breaking strength and elongation are major parameters that affect the bursting strength of knitted fabric.

Shahbaz, et al. [16] stated that fabric strength reveal that the effect of machines and blending ratio is highly significant.

Kavuşturan et al. [17] stated that knitting structure significantly affected the bursting strength.

Candan and Onal [18] examine that the 100% CO samples knitted from ring spun yarns tend to have lower pilling rates than those constructed from the 100% CO O.E. spun yarns. This may be due to the ring spun yarns are hairier than the O.E. spun yarns. Knit from blend yarns tend to have a greater tendency to pill than knits from 100% CO O.E. yarns. Lacoste structure has the highest resistance to pilling while single jersey fabrics have the lowest pilling rates.

1.3. Purpose of This Thesis

Fabric pattern must be evaluated not only as an appearance property of a knitted fabric but also an important structure parameter indeed. Despite the fact that fabric properties are influenced with a wide range by this structure parameter, the literature survey shows that there is almost no detailed research on this parameter. In the thesis, the investigating influences of the tuck stitch on fabric physical properties in an attempt to suggest the suitable knitting types for usage is studied. In addition to knitted fabrics with the tuck stitch single jersey fabric was also included to compare with plain knit in this experimental study. To determine effects of dyeing knitted samples were dyed.

Shortly, the aims of this study are ;

- to investigate the influences of the tuck stitch on the performance of circular knitted fabrics manufactured by using weft knitting technology.
- to compare knitted fabrics having the tuck stitch with single jersey fabric.
- to determine effect of dyeing on the properties of fabrics having the tuck stitch.

Eleven different circular knitted fabrics having the tuck stitch and single jersey were produced on Monarch machine with single bed for this study.

The samples were knitted by the same Ne 30, 100% cotton carded ring yarn.

The following properties of fabrics were tested;

1. Fabric weight
2. Thickness
3. Bursting strength
4. Pilling resistance
5. Abrasion resistance
6. Dimensional stability
7. Spirality

Also, they were tested as gray and dyed with the equipments and devices in the laboratory of Textile Engineering Department of Gaziantep University and USAM (Association of University and Industry Adana Centre) according to TSE standards.

1.4. Structure of Thesis

Chapter 2 includes the information about knitting. Classifying of knitting, terms and elements of circular kntting machines, basic loop types and knitting structures were reviewed. Properties and formation of the standard loop, the tuck stitch and the miss stitch were examined. Properties of RL (s.jersey, lacoste) and RR (ribana, interlock) structures were discussed.

In Chapter 3; the fiber, yarn, knitting machine are used in the knitted samples, dyeing method and the samples were introduced. Totally, 11 different knitted fabrics with the tuck stitch and 1 single jersey fabric were tested for this experimental study. Bursting strength, dimensional stability, thickness, spirality, abrasion resistance and pilling resistance testing methods were also given in Chapter 3.

In Chapter 4; results of the tests were given and discussed. According to the test results bursting strength, dimensional changes, abrasion resistance, pilling resistance, spirality and thickness values of knitted samples were examined and discussed. Besides knitted samples having the tuck stitch were compared with each other and single jersey fabric and also gray fabrics were compared with dyed fabrics. Graphical analyses of results were given. ANOVA, CORRELATION and REGRESSION statistical test methods were used for analyzing the test results.

Lastly in Chapter 5; conclusion of thesis and recommendations were given.

CHAPTER 2

KNITTING

2.1 INTRODUCTION

The concept of the making of fabric on more than one needle by interlooping a thread or several parallel threads is known as knitting [2].

The art of hand knitting has been practiced for thousands of years. How this art was learnt by ancient human is still a mystery and so is the country and time of its origin. The present knitting industry is based on the invention of William Lee, who succeeded in the mechanization of the interlooping of yarns four hundred years ago [19,20].

In the 19th century power was applied to the knitting machines and simultaneously circular knitting machines appeared on the scene. A marked development in this technology has taken place over the last fifty years. Developments in the 20th century increased the production speeds of the machines and offered wide pattern of knitted fabrics. Now computer controlled knitting machines have come on the scene, which are highly versatile. Knitted garments have now become every day dress.

2.2 CLASSIFICATION OF KNITTING

There are two main industrial categories of machine knitting; weft knitting and warp knitting as shown in Figure 2.1. 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 2.2a), and a vertical set of yarns (warp) could be used to produce a warp knitted fabric (Figure 2.2b) [14]. Table 2.1 shows the comparison between warp knitting and weft knitting according to some criterias given below.

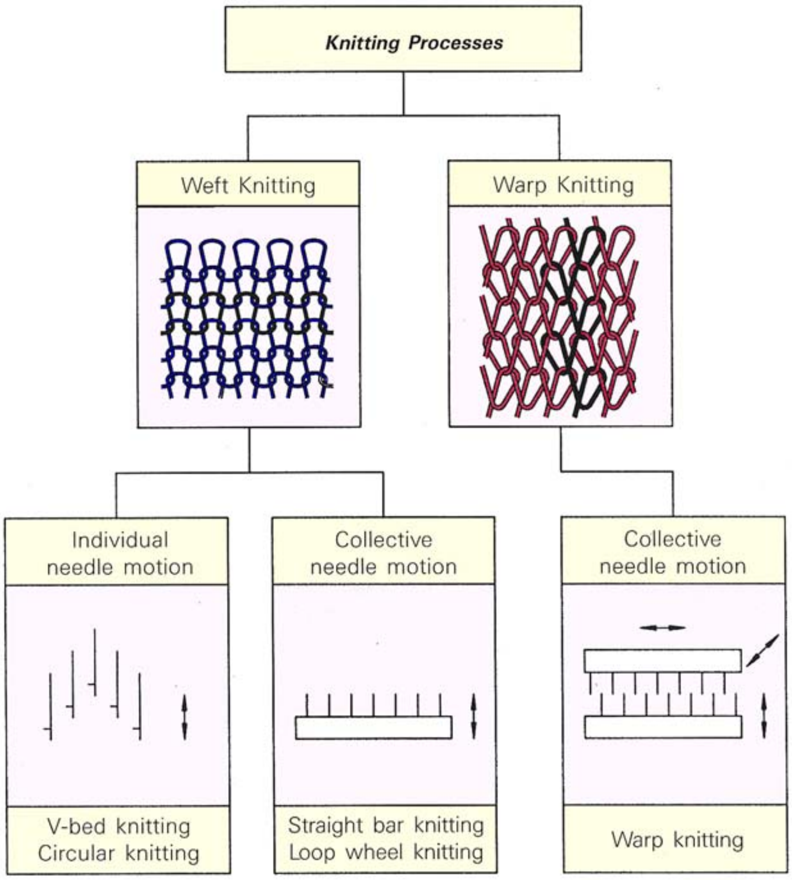
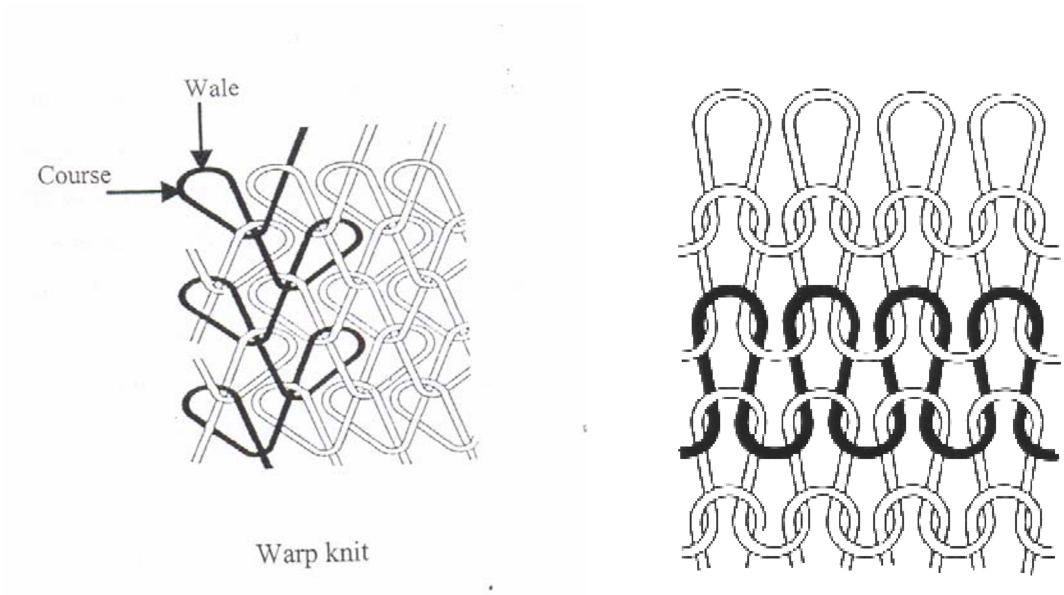


Figure 2.1 Classification of knitting [14]



(a) Warp knitted fabric (b) Weft knitted fabric

Figure 2.2 Type of knitted fabrics [14]

Table 2.1 Comparison of warp knitting and weft knitting with the given criterias [21]

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
Structur 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

2.2.1. Warp Knitting

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

2.2.2 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 ones 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 2.3 and Figure 2.4). 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) [14]. Weft knitting machines are classified as; flat knitting machine and circular knitting machine.

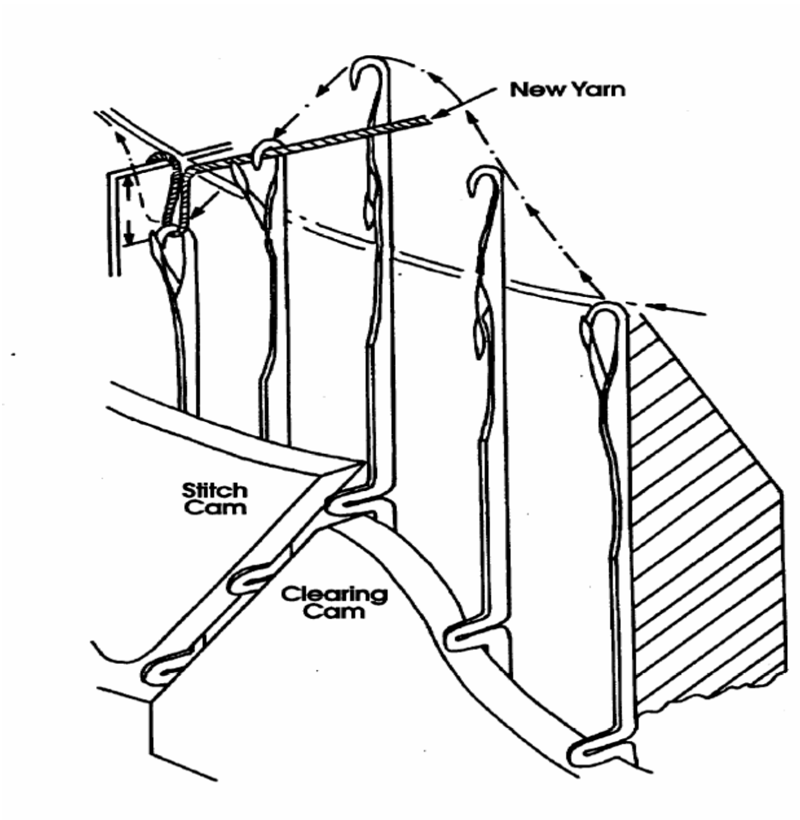


Figure 2.3 Loop formations on a circular knitting machine[22]

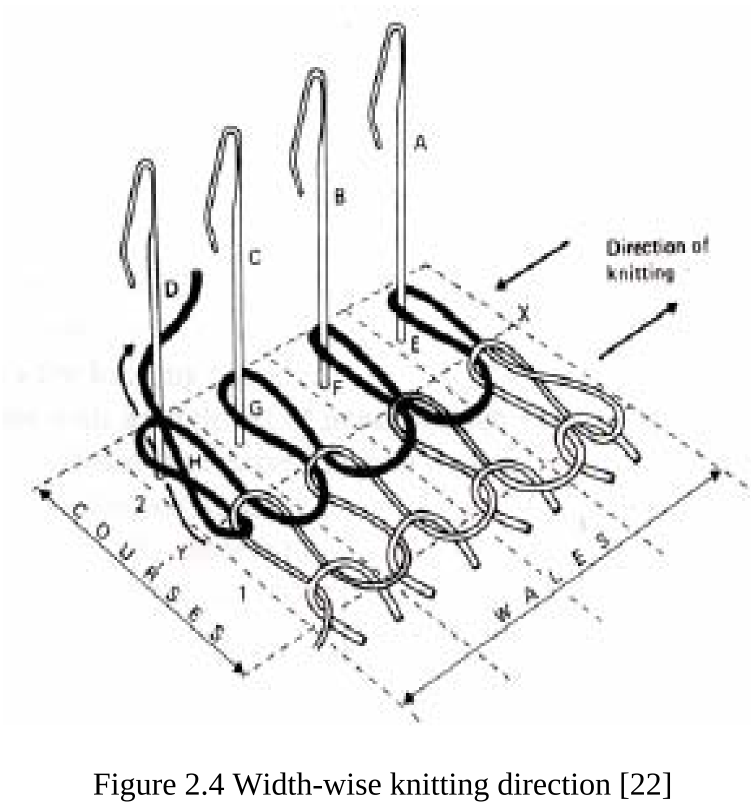


Figure 2.4 Width-wise knitting direction [22]

2.2.2.1 Flat Knitting

The flat machines have all the needles arranged in straight rows. Usually there are two beds in an inverted V position to hold the needles. The yarn is fed back and forth 'across the width of the fabric and flat lengths of fabric or garment parts are produced.

2.2.2.2 Circular Knitting

Circular knitted fabrics are flexible fabrics because of the special linking of the loops forming it. For this reason, they conform to the contours of the body much better than woven fabrics and do not restrict the movements of the body.

In circular machines the yarn is fed continuously in one direction to the needles which are arranged in circular formation, and consequently the fabrics or garment blanks produced are usually tubular. In multifeeder system, instead of feeding of only one yarn to the circular machine, and being idle of most of the needles while the yarn is being knitted on its circuit, a succession of yarns is fed to the needles. This result that there are numbers of knitting zones around the periphery. If 24 yarns are supplied to a multi-feed system, 24 courses will be knitted simultaneously. The tube of fabric will be composed of spirals of yarns [3] (Figure 2.5).

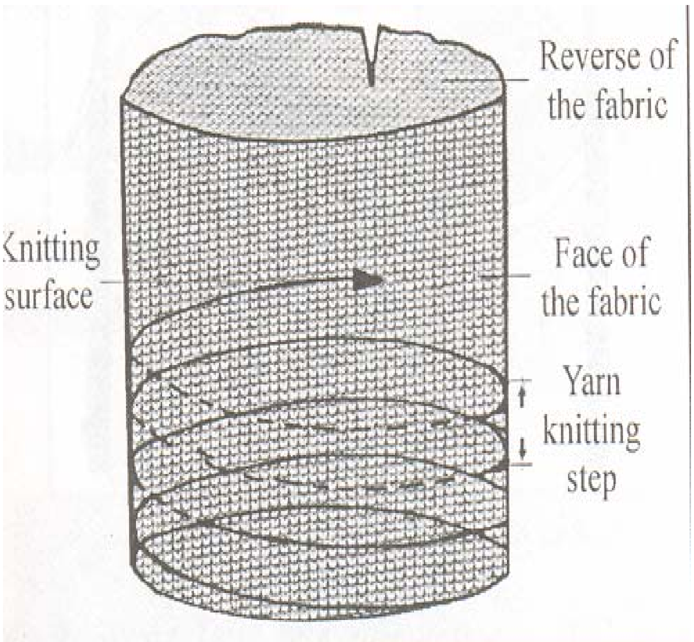


Figure 2.5 Tubular wefts knit fabric [3]

2.3 CIRCULAR KNITTING MACHINES

Circular knitting machines are in a cylindrical construction as can be understood by their name. The needles are inserted in the needle canals opened on the needle beds upon the cylindrical main body. In these machines, during the circular movement of the needle beds, needles are separately moved in the canals by the locker and the knitting process is realized by inserting yarns over to the needles. In order that loops are easily and comfortably produced, there are sinkers positioned in a horizontal way to the needles.

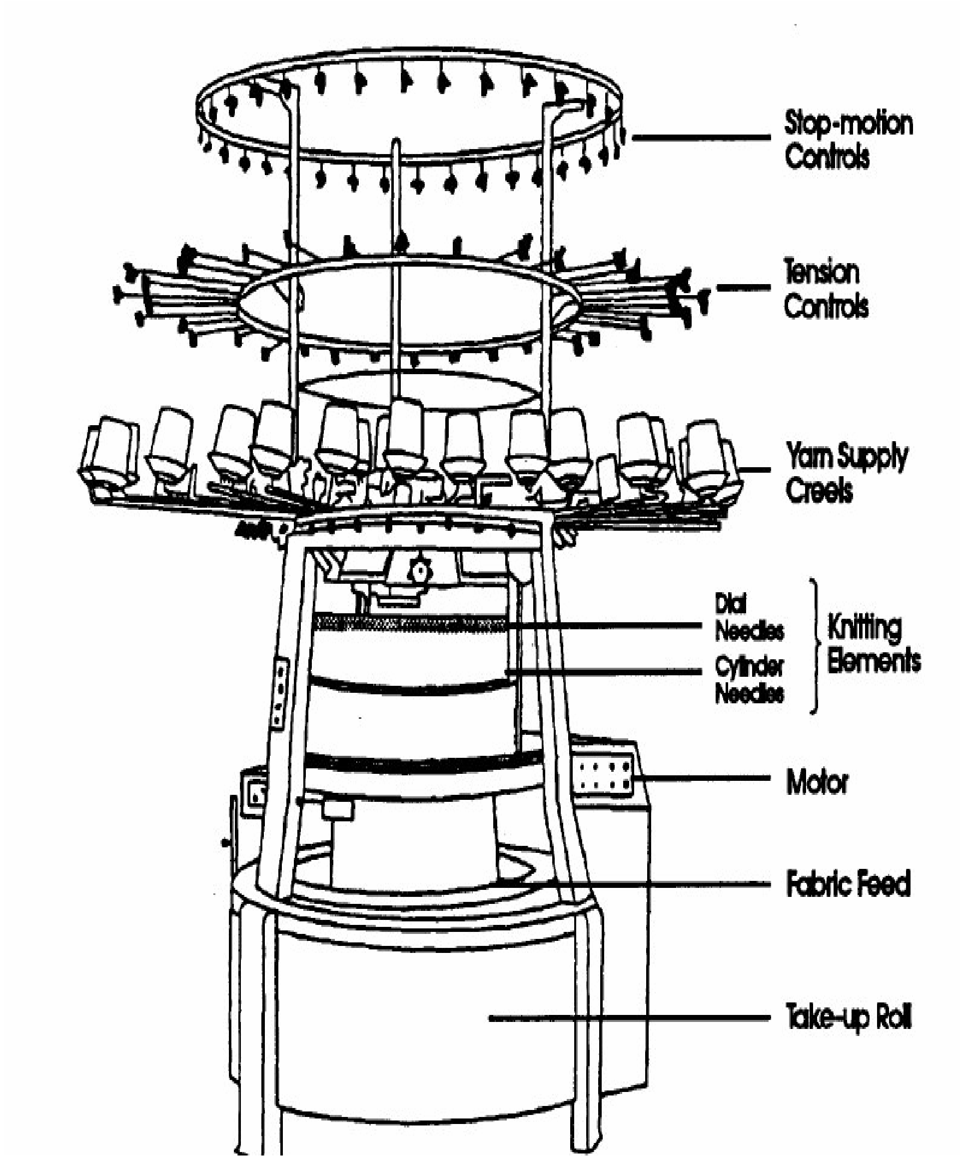


Figure 2.6 The elements of circular knitting machine [22]

2.3.1 Main Terms Relating on Circular Knitting Machine

1) The needle: The hooked metal needle which forms loops and wales is the principal knitting element of the knitting machine [8].

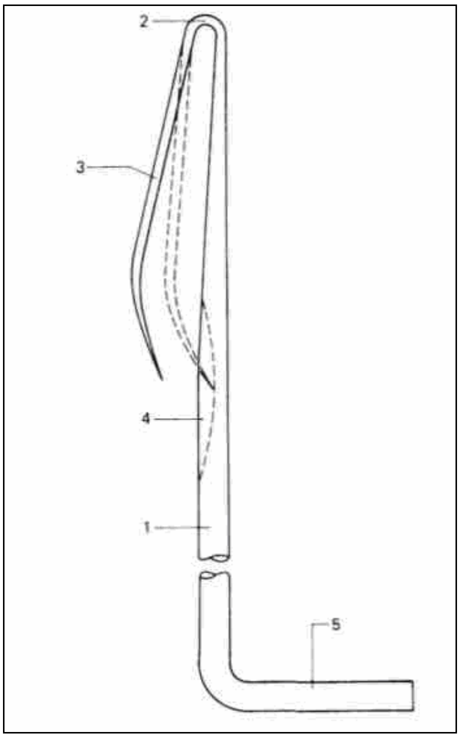


Figure 2.7 Bearded needle [8].

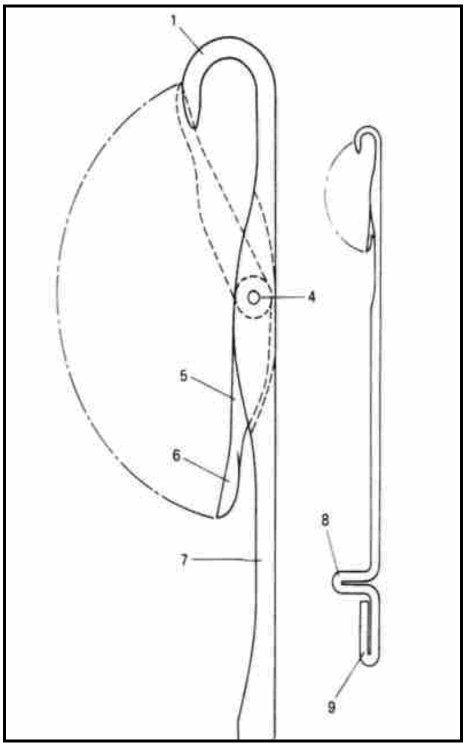


Figure 2.8 Latch needle [8].

2) The sinker: The sinker is the second primary knitting clement. It may perform functions of loop- formation, holding-down, knocking-over dependent upon the machine's knitting action and consequent sinker shape and movement [8].

3) Knitting cams: The angular knitting cam (see Figure 2.9) acts directly onto the butts of needles or other elements to produce individual or serial movement in the tricks of a latch needle weft knitting machine [8].

4) 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) [23].

5) Tricks: Slots which guide needles during knitting.

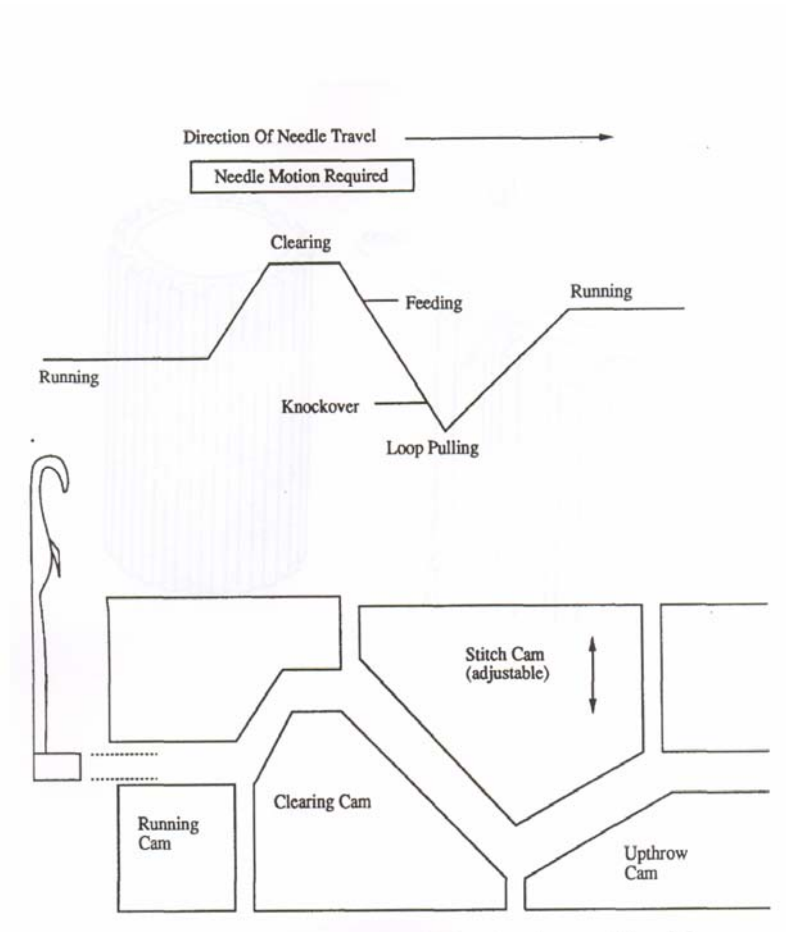


Figure 2.9 Cam system of single jersey machine [8].

6) 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.

7) Cut of Cylinder, NPI, (E): The number of needles per inch in a weft knitting machine. It also refers to number of needles per inch used in the construction of a weft knitted cloth [24].

8) Gauge: A term often used confusingly. For circular needle knitting, it is an arbitrary term which expresses the thickness of the knitting needle or of the sinker [24]. It can be expressed as distance between two relative knitting needles (Figure 2.10).

9) Machine diameter (pus): The measurement of the diameter of the cylinder needle bed in imperial inches. Figure 2.11 shows pus of a circular knitting machine.

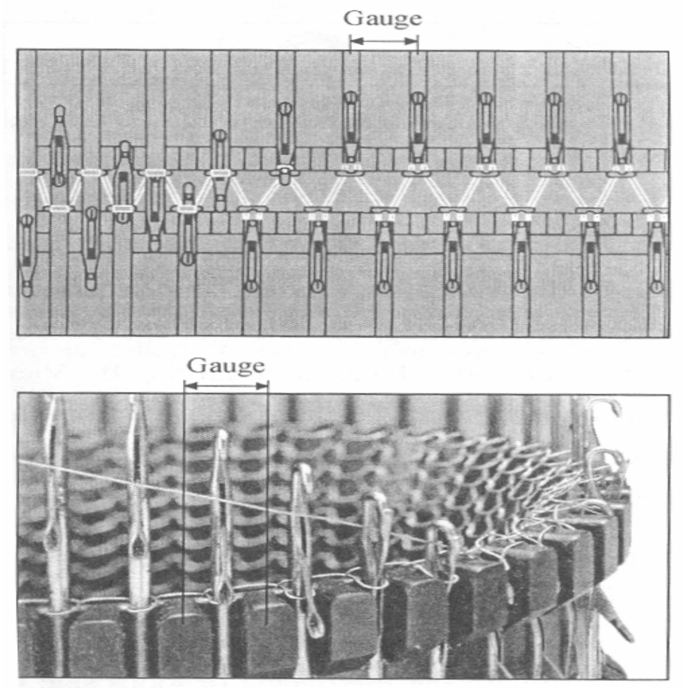


Figure 2.10 Illustration of gauge schematic on machine. [24].

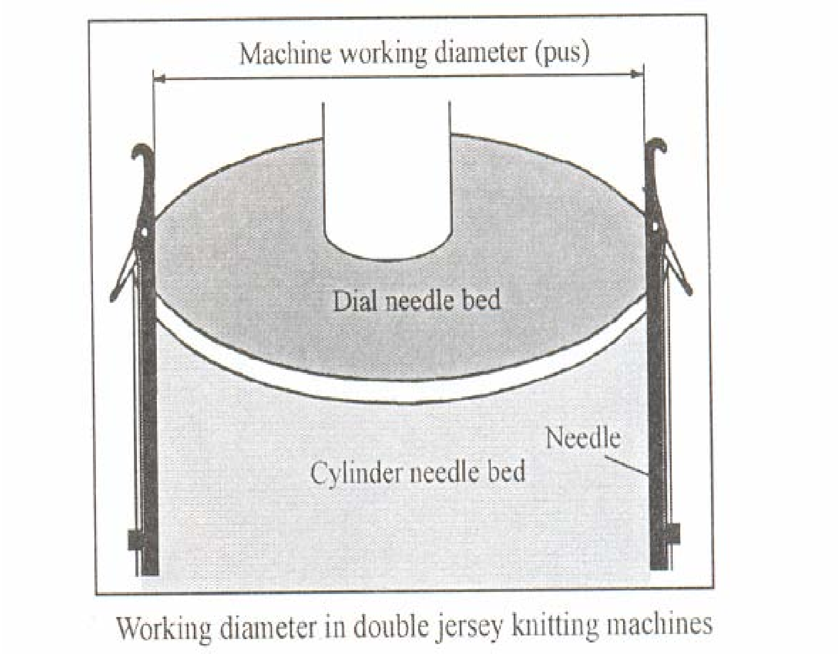


Figure 2.11 Diameter of circular knitting machine [24].

10) Cylinder: The part of a knitting machine that holds those knitting needles and is in a vertical position during knitting [25].

11) Dial: A horizontal plate which contains slot and horizontal needles.

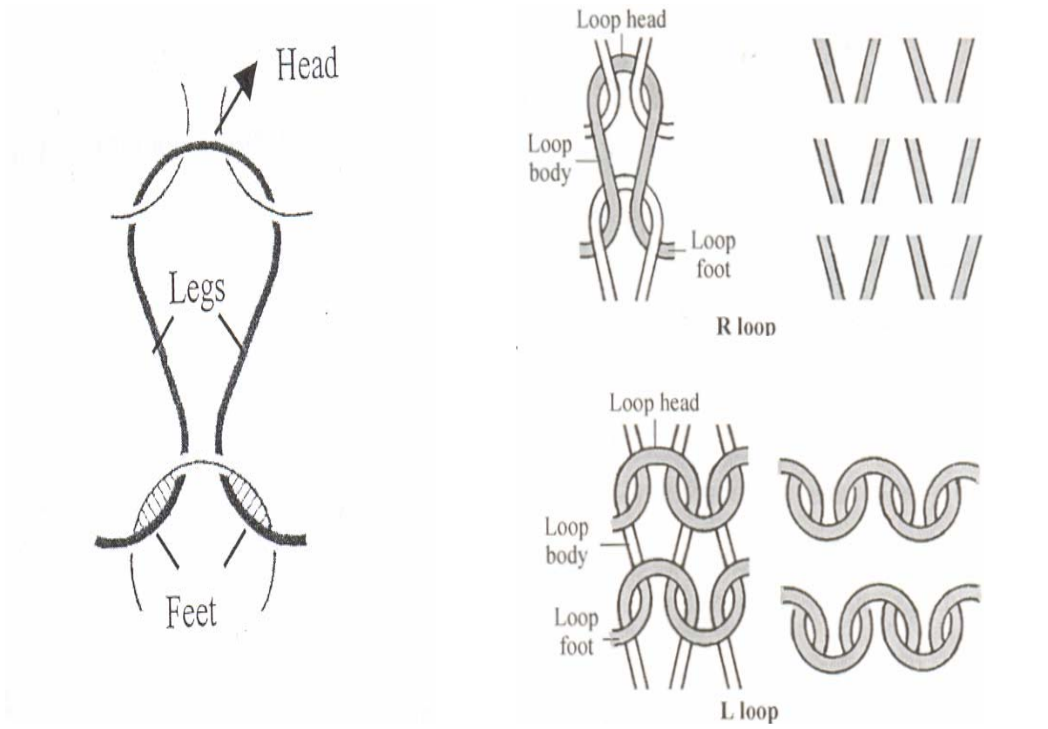


Figure 2.12 Structure of loop [8].

12) 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.

13) The Loop: The basic shape into which yarn is formed in the process of knitting. All knitted fabric is made up of a succession of loops. The structure of loop and parts of a single loop (head-legs) are illustrated in Figure 2.12.

14) 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 2.13)

15) 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 2.14).

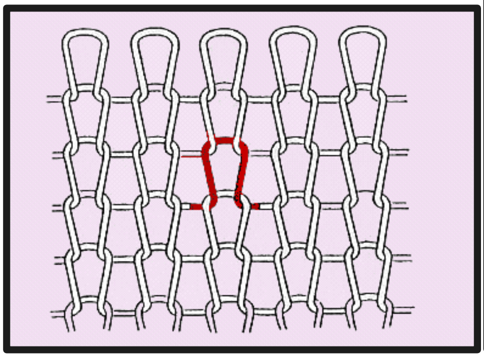


Figure 2.13 Technical face [8].

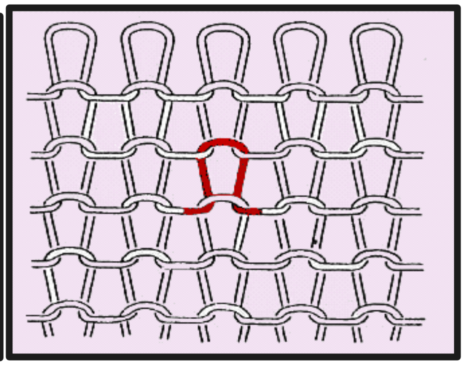


Figure 2.14 Technical back[8].

16) Needle and Sinker Loops: The yarn lies in the plane of the fabric in what is called a snake curve, and the loops which are drawn through the previously formed loops by the needle are called needle loops. However, since the yarn is continuous there must be connecting loops of opposite curvature; these are called sinker loops. These loops are formed over thin plates called sinkers (Figure 2.15).

17) Stitch: A stitch is the combination of loops from adjoining threads forming a fixed part of the fabric and the duplication of which forms the whole fabric. A stitch is frequently considered to consist of the shape formed by the entire length of yarn from any point on a loop to the corresponding point on a horizontally adjoining similar loop.

18) Top and Bottom of Stitch and Fabric: In a completed stitch, the needle loop is the top of the stitch and the sinker loop the bottom. The bottom of the fabric is that which is knit first and the top which is knitted last.

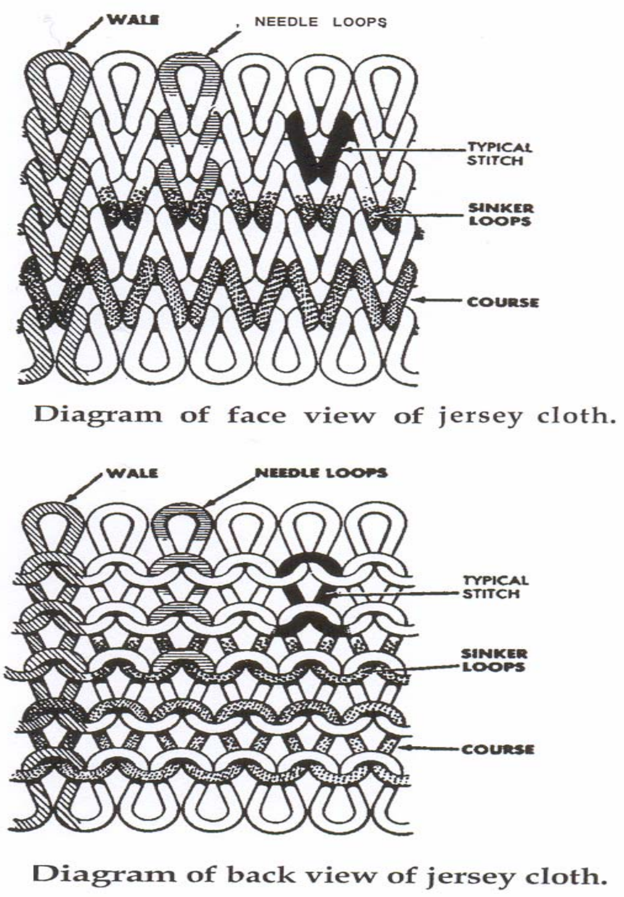


Figure 2.15 Needle and sinker loops [8].

19) Course: A row of loops extending across the full width of the fabric (Figure 2.16).

20) Wales: A 'column' of loops that running down the length of the fabric representing the loops knitted by one needle (Figure 2.17).

21) Stitch length: The length of yarn in one loop.

22) Course length (LFA-Longueur de Fil Absorbée - Absorbed yarn length per course): The yarn length which is absorbed for knitting one tour around the circumference of the needles.

23) Average stitch length: The course length divided by the total number of needles in the machine.

24) Stitch density: Stitch density refers to the total number of loops in a measured area of fabric and not to the length of yarn in a loop (stitch length). It is the total number of needle loops in a given area (such as a square inch, or three square centimetres).

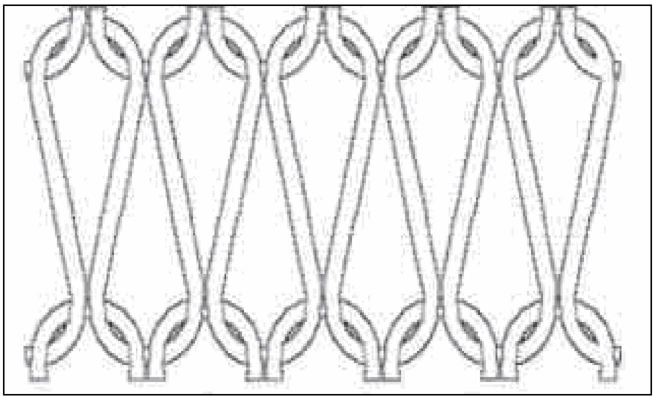


Figure 2.16 A course [8].

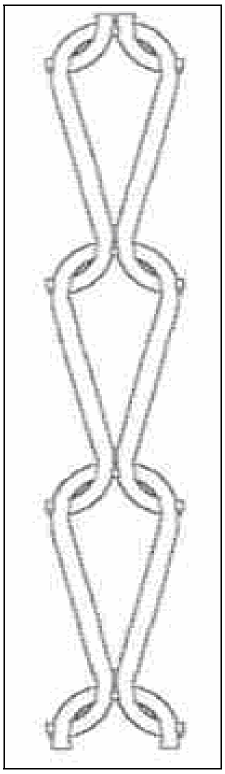


Figure 2.17 A wale [8].

2.4. BASIC LOOP TYPES

2.4.1 The Standard Loop

The basic loop has two different faces according to the relative positioning of the producing needle and the fabric. The face loop, produced by a needle in the front needle bed, exhibits the arms of the curved formation (Figure 2.18a). The reverse loop, produced by a needle positioned in the rear needle bed, exhibits the arcs of the top and the root of the structure (Figure 2.18b).
The standard loop is a flexible formation, can easily change its shape under small loads and is responsible for the stretchable characteristics of the fabric [8].

2.4.1.1. The loop formation

The knitting action of a latch needle and holding-down sinker during the production of a course of plain fabric are shown in Figure 2.19 a-e.

a) Tucking in the hook or rest position. The sinker is forward, holding down the old loop whilst the needle rises from the rest position.

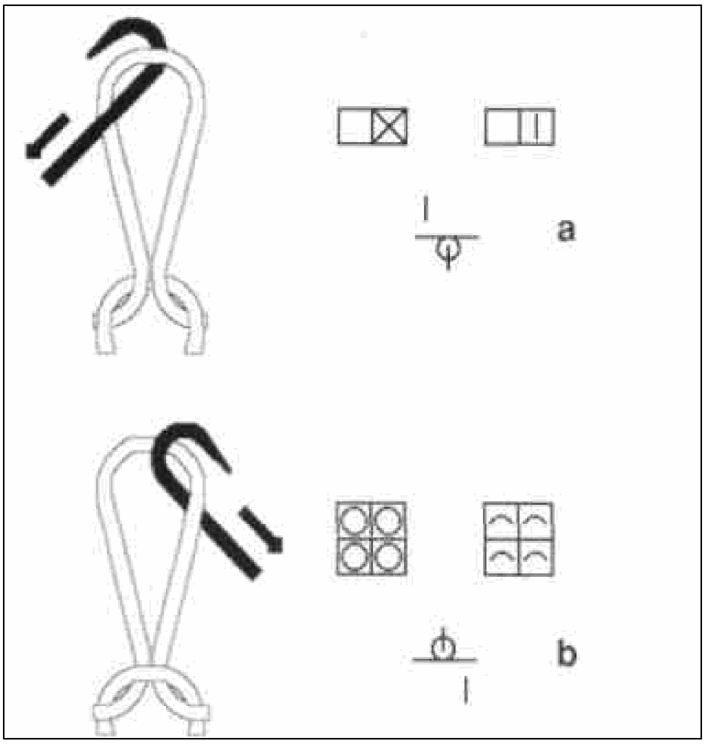


Figure 2.18 The standard loop [8].

b) Clearing. The needle is raised to its highest position clearing the old loop from its latch.

c) Yarn feeding. The sinker is partially withdrawn allowing the feeder to present its yarn to the descending needle hook and also getting free the old loop so that it can slide up the needle stem and under the open latch spoon.

d) Knock-over. The sinker is fully withdrawn whilst the needle descends to knock-over its old loop on the sinker belly.

e) Holding-down. The sinker moves forward to hold down the new loop in its throat whilst the needle rises under the influence of the upthrow cam to the rest position where the head of the open hook just protrudes above the sinker belly.

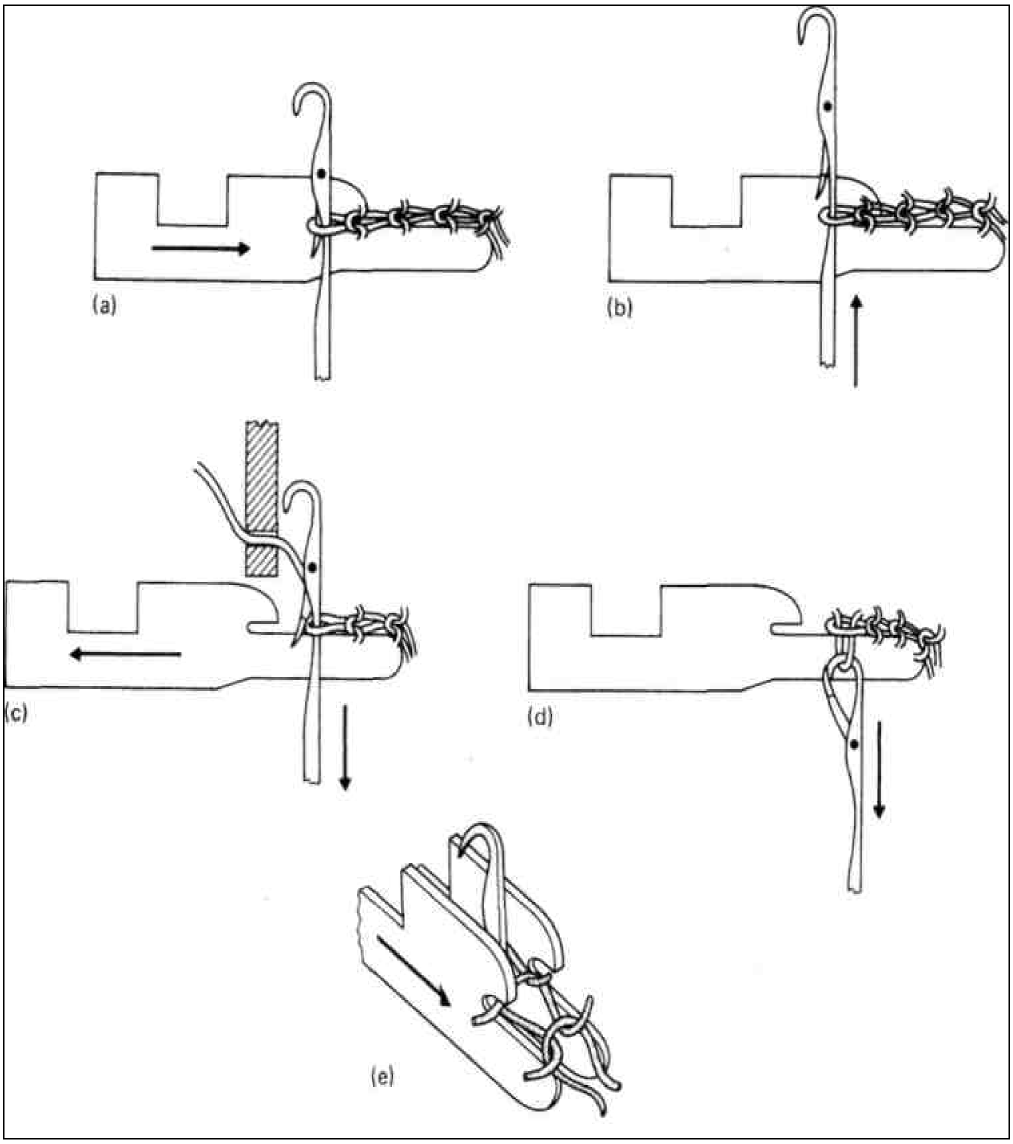
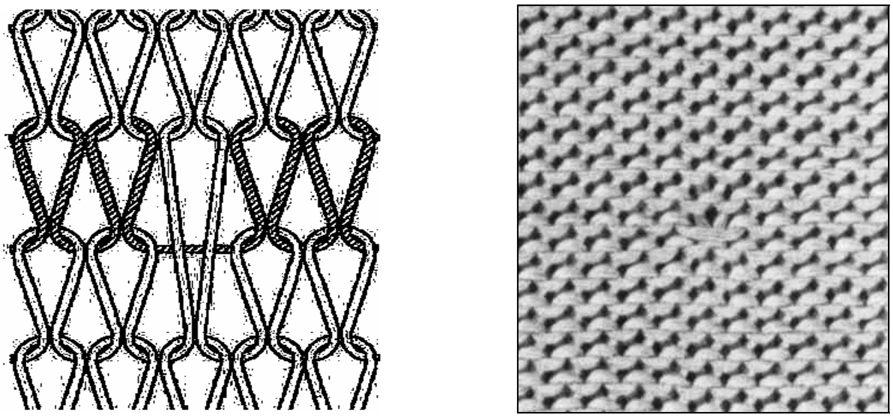


Figure 2.19 Knitting cycle of a single jersey latch needle machine. [8].

2.4.2. The Miss Stitch

As suggested by its name, the miss stitch effect is created when one of the knitted loops is missed during the production sequence [8]. The effect created on the face of the fabric by a knitting sequence called "Missing" is illustrated in Figure 2.20a. As the schematic illustration shows, the main effect is created by two elements i.e. an enlarged knitted loop and a straight element of yarn.

A macro photograph given in Figure 2.20b shows the actual configuration of the miss stitch. The deformed and the stretched loops tend to rob some yarn from its adjacent loops and so reduce them in size. When the needle notation system is used, the yarn is simply drawn as skipping the inactive needles shown in Figure 2.21, much the same as in actual practice.



(a) The schematic figure of miss stitch (b) The macro photographic miss stitch

Figure 2.20 Miss stitch [8].

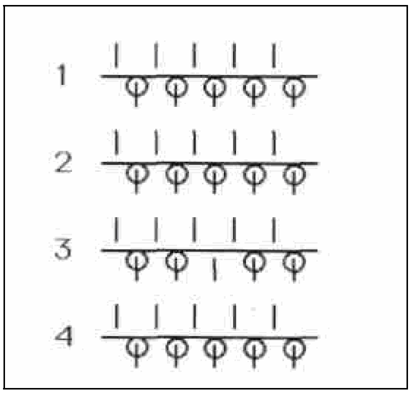


Figure 2.21 The schematic figure of miss stitch in needle notation system[8].

2.4.2.1 The Loop Formation

The series of diagrams given in Figure 2.22 illustrate the forming procedure of a miss stitch.

1. Only two of the needles ascend to clearing position and clear the latches. The needle in the centre fails to ascend and remains in the lower position while holding onto its loop.
2. The yarn carrier travels across the machine feeding new yarn into the hooks of the active needles.

3. Active needles descend to knockover and form new loops. The needle in the centre creates the "Miss" effect by retaining its loop.

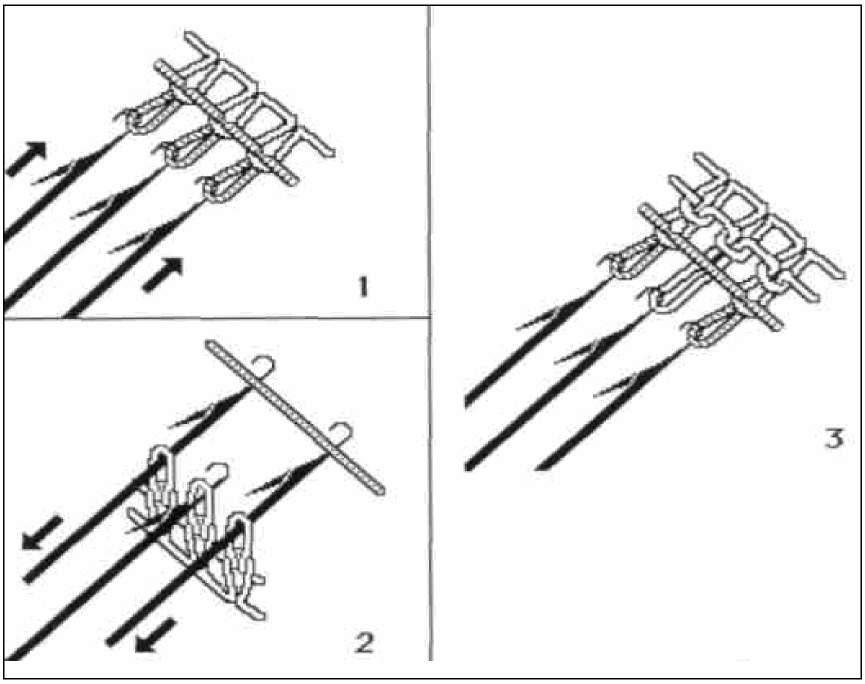


Figure 2.22 The miss stitch formation [8].

2.4.2.2 The Properties and Use of the Miss Stitch

1. Knitting plain knits. When the raising cams of one needle bed are completely withdrawn to miss all the needles, the machine knits with the other needle bed only.

2. Knitting a variety of rib structures. Besides the 1x1 rib, all other rib structures require some of the needles to miss.

3. Improvement of the fabric's widthwise stability. A missed loop creates a short connection between two adjacent wales and eliminates the accordion effect of the rib shown in Figure 2.23. Straight segments of yarn formed in the fabric ensure that the stretchability of the structure is reduced. The result is a much more stable construction.

4. Decrease of fabric width. Short connections between the wales, as mentioned in the previous paragraph, affect the fabric width. A large number of miss stitches in a course reduce the fabric width considerably.

5. The production of Jacquard structures. The main use of miss stitches in a selected fashion is the creation of Jacquard fabrics. The long segments of yarn created by the yarn misses are called "Floats". They are presented on the reverse side of the fabric given in Figure 2.24 and in some cases can cause snagging problems when the garment is worn.

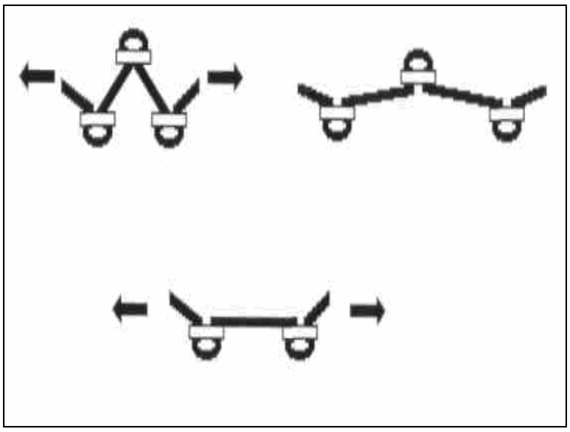


Figure 2.23 Reducing stretchability with miss stitch [8].

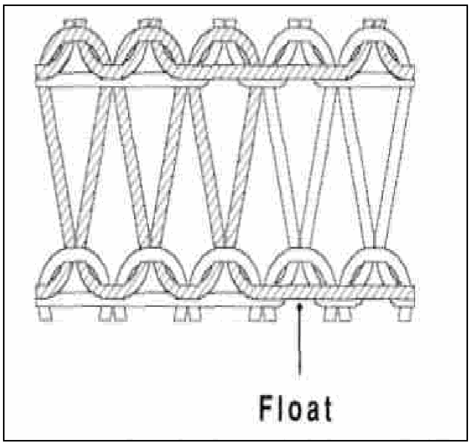


Figure 2.24 Floats [8].

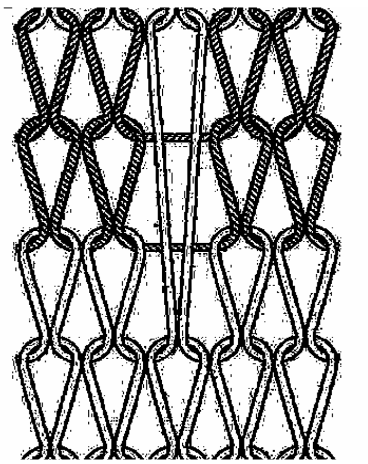


Figure 2.25 The missing sequence [8].

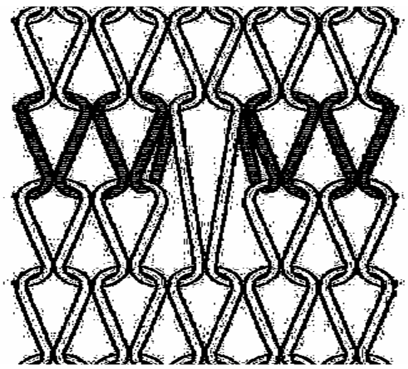
6. The use of the structural deformation. The structural deformation resulting from a missing sequence can be used as a patterning effect on the fabric. The miss stitches have to be arranged according to a predetermined design to create such a pattern.

To increase the size and boldness of the deformation, the missing sequence can be repeated as shown in Figure 2.25. The same needle is missed for two consecutive courses, the held loop is stretched even more and the deformation is greater. The repeated missed sequence is limited by the properties of the yarn forming of the held loop. The load is placed on this yarn and the number of misses possibly depends on its tensile properties [8].

7. Marking of garments. The different appearance of the missed loop can be used for marking of cutting lines. Arm holes or a "V" neck lines can be defined as garments during the knitting process.

2.4.3. The Tuck Stitch

Figure 2.26 shows a stitch created by a knitting sequence called "Tucking". The effect is created by an enlarged knitted loop with a segment of yarn tucked behind it. The tuck stitch is formed, as suggested by its name, when the yarn is tucked into the structure by the needle, instead of being formed into a loop. The stretched deformed loop originated as a normal knitted loop which was held by the tucking needle while the other needles knitted an additional course. A macro photograph given in Figure 2.27 shows the actual yarn configuration of the tuck stitch effect. As with the miss stitch, the deformed stretched loop, robs some yarn from the adjacent loops thus reducing them in size [8]. In the needle notation system illustrated in Figure 2.28, the yarn is marked as fed into the needle without forming a loop.



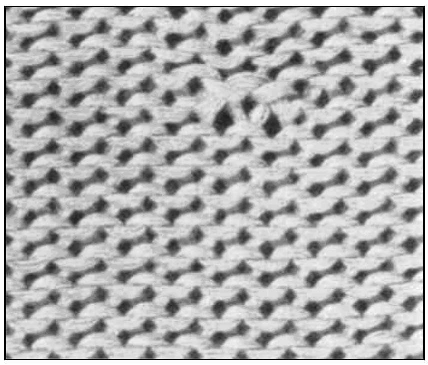


Figure 2.26 The schematic figure of tuck stitch   Figure 2.27 The photographic tuck stitch[8].

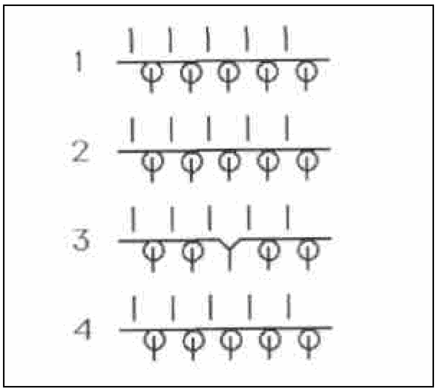


Figure 2.28 The schematic figure of tuck stitch in the needle notation system [8].

2.4.3.1 The Loop Formation

In the series of diagrams in Figure 2.29, the forming procedure of a tuck stitch is shown. The different steps in the sequence are:

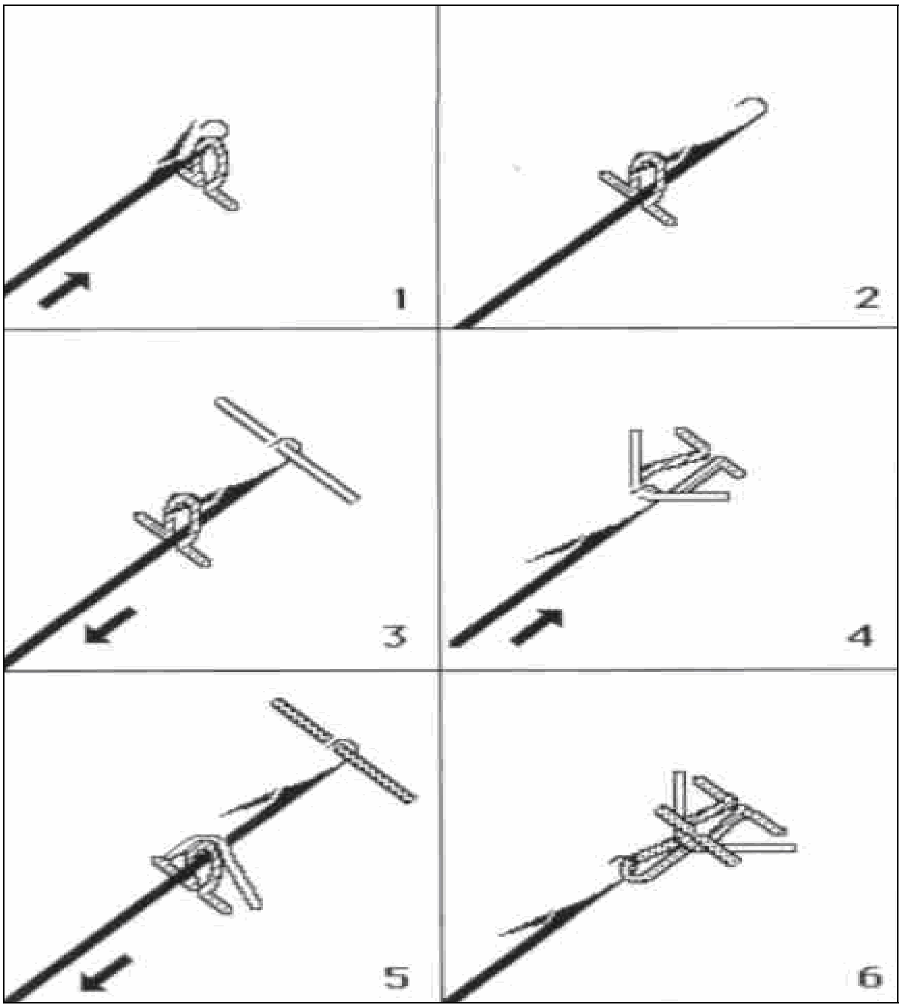


Figure 2.29 The tuck stitch formation [8].

1. The previously formed loop is in the hook of the needle which starts to ascend.

2. The needle's ascent is stopped short of clearing position with the loop still placed on the needles latch.

3. A new yarn is fed into the descending needle. Since the new yarn is not pulled through the previous loop, it does not acquire a loop shape. Instead, it is simply placed in the hooks enclosure together with the previous loop. The adjacent needles have formed new loops during this sequence, so the previous loop held by the tucking needle is now stretched and deformed shown in Figure 2.24.

4. The needle now ascends to clearing position and both previous loop and tucked yarn drop under the latch.

5. The descending needle is fed by a yarn. The previous loop together with the tucked yarn slides under the latch closes it and slides over the hook.

6. The new yarn is pulled into knockover position and forms a new loop. Note that the tucked yarn is hooked between the two knitted loops.

2.4.3.2. The Properties and Use of the Tuck Stitch

1. Fabric patterning. The different appearance of the tuck stitch, in comparison with the regular standard loop background, can be used for patterning. The stretched elongated held loop relaxes on leaving the knitting zone, forming a small buckle on the face of the fabric. To increase the effect, a needle can tuck for consecutive knitting sequences. The illustration in Figure 2.30 shows the arrangement of the yarn after two consecutive tucking operations. The held loop is further stretched and the needle has gathered three yarns within the hook before clearing. Consecutive tucking operations and the shrinking forces applied by the held loop can create large knobs on the fabric plain.

The number of consecutive tucking operations is restricted by the tensile strength of the yarns in the held loop. It is also limited by the size of the needle's hook in relation to the collective thickness of the yarn ends. While in older machine types four consecutive tucks have been possible, modern equipment can produce up to eight or even ten such consecutive sequences.

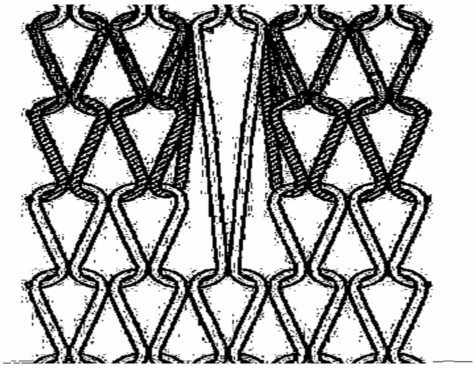


Figure 2.30 The two consecutive tucks [8].

2. Increasing of fabric weight and thickness. The tuck yarn is added to the standard loop without a knitting sequence and no new loop is produced. A large number of tuck stitches can thus add to the weight and thickness of the fabric.

3. Increasing of fabric width. The principle described above also shows why fabric width increases as a result of a large number of tucks. This increase is caused by the presence of more yarn in the structure, and the restrictive forces applied by the tuck courses to the tendency of the rib to contract.

4. Insertion of problematic yarns. Not all yarns are able to be formed into the shape of a loop due to their mechanical properties. With tucking procedures, such yarns can be inserted into the fabric with only a minimum of bending stresses (Figure 2.31).

Every knitting machine is restricted by the thickness of the yarn which can be processed and turned into a fabric. Contrary to popular belief, the thickness of the yarn is not limited by the size of the hook.

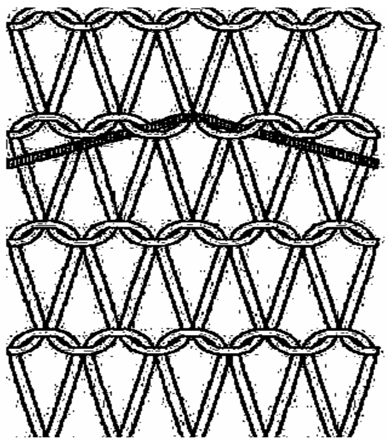


Figure 2.31 Reducing of bending stresses with tuck stitch [8].

It is limited by the size of the trick in the needle bed into which it is pulled in the knockover position. Tucked yarns do not need to be pulled into knockover position. Yarns which are quite too thick for regular knitting can thus be inserted in the fabric by tucking.

5. Shortening of Jacquard floats. Long floats can be formed on the reverse side of the fabric as a result of a Jacquard patterning sequence. These floats can easily be pulled by such objects as a ring or a wrist watch, resulting in loop distortion on the fabric face and damage to the garment. To reduce the size of such floats, lessening the danger of snagging, tucks can be introduced along the float. In this respect, the tuck construction has two advantages:

a. No loop is formed so no yarn is wasted.

b. The tucked yarn is placed behind the face loop and does not interfere with the design.

The reverse side of a Jacquard structure with long floats is illustrated in Figure 2.32, with a tuck stitch introduced into one float to show its advantages.

6. Garment marking. The different appearance of the tuck stitch, in comparison with the standard loop background, can be used to mark cutting lines in the garment during the knitting process. Furthermore, the knitting machine can code mark the garment in an obscure place to allow machine identification for quality control during later production stages.

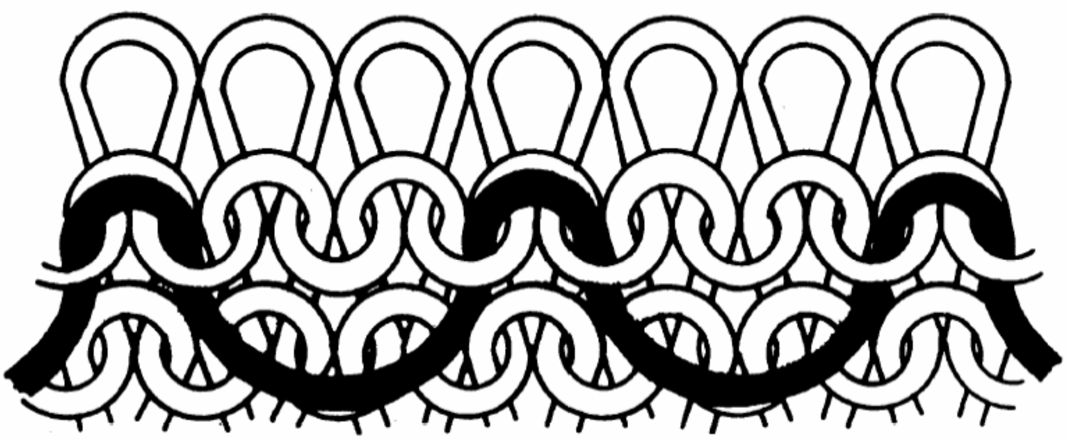


Figure 2.32 Using of the tuck stitch in jacquard structure [26].

2.5. BASIC CIRCULAR KNITTED FABRICS

Circular knitted fabrics are those which are produced in tubular form on circular knitting machines. Machines work in the single/multiple yarn knitting system. These machines carry the knitting elements inserted in the form of circle, producing loop courses in a helical way.

Knitting types with RL (s.jersey, lacoste, fleecy etc.), RR (ribana, interlock, cardigan etc.) and LL (purl) structures (see Figure 2.33) can all be produced on circular knitting machine.

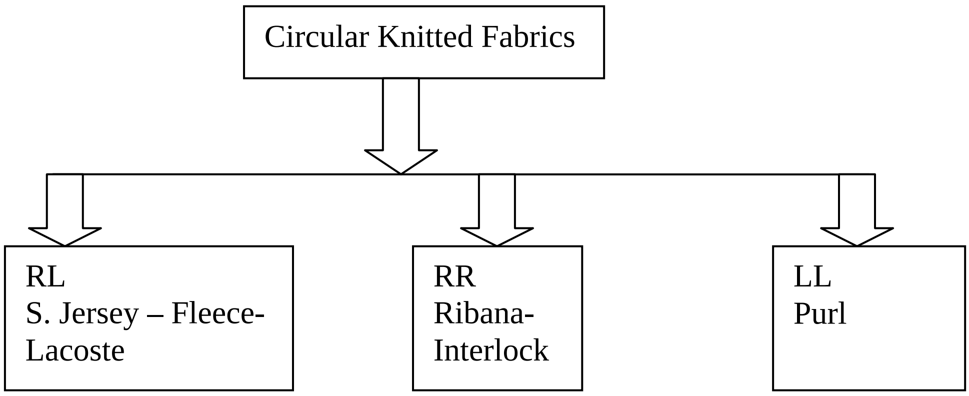


Figure 2.33 Basic weft knitted structures [8].

2.5.1 RL Structures

This kind of knitted structures consists of single basic loop structure. These structures have two different sides (right side and left side). Jersey fleece, velour, and terry fabrics all originate in loops protruding from the surface of the cloth. These loops are subsequently cut and brushed or sheared, with the exception that terry is left uncut.

2.5.1.1 Single Jersey

In the jersey stitch, vertical components of the loops appear on the right side and horizontal components (courses) are seen on the left side. The face side of jersey usually has a softer handle than the reverse side [24].

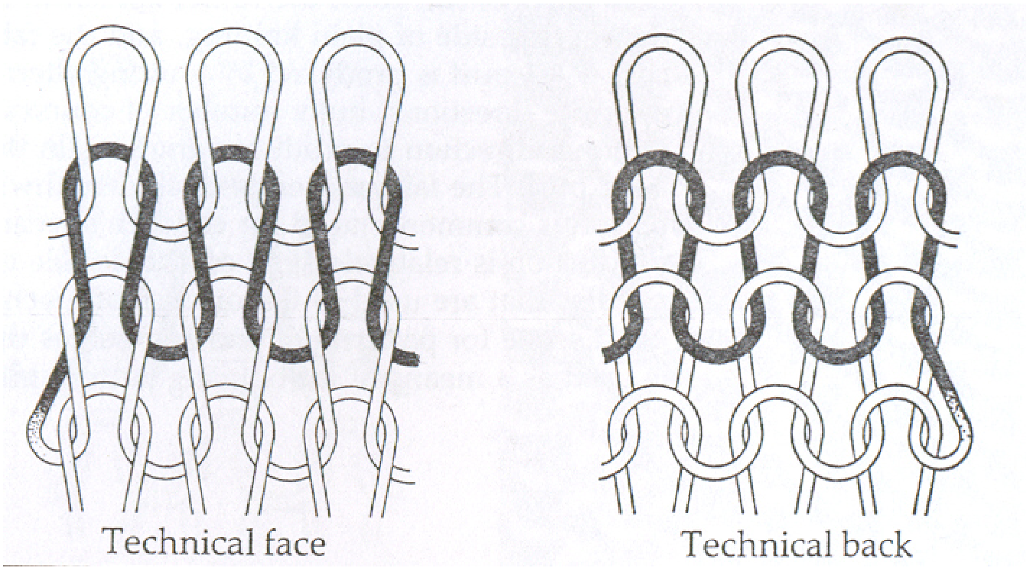


Figure 2.34 Single jersey structure [24].

Single jersey is the plain RL fabric knitted on single plate circular knitting machine shown in Figure 2.34. It contains only loops in the knit repeat having no tuck, miss knit [3]. However, the patterned structures are obtained by the introduction of float or tuck stitches. S.jersey is a fairly elastic fabric in which face and reverse sides are different in appearance and which tends to curl [3].

In Figure 2.35, the single jersey structure shows two courses and three wales. Plain structure or single jersey is the simplest weft knit structure and is formed by the inter-meshing of a number of loops from side to side and to bottom. The single jersey structure is composed solely of knit loops knitted on one bed of needles. Its production rate is very high because of stitch simplicity, and it is relatively inexpensive to produce because of machine simplicity [4].

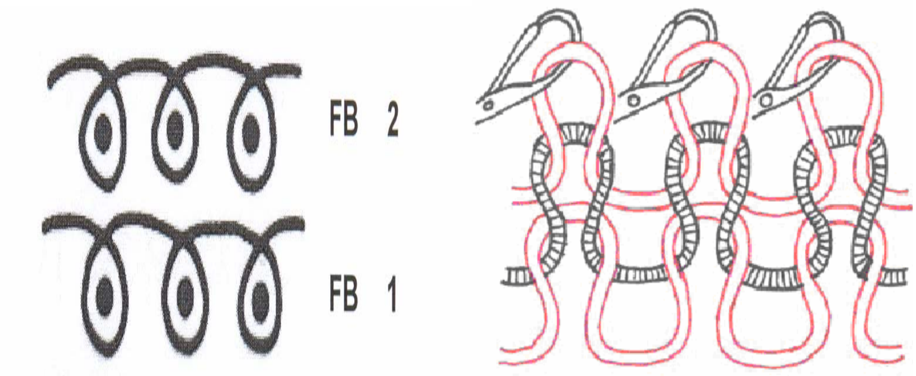


Figure 2.35 Diagrammatic and schematic figures of single jersey [8].

Ajgaonkar [5] described that this fabric is unbalanced because it is knitted on one set of needles. Therefore the loops tend to curl towards the front at the top and bottom ends and towards back at the sides, which makes curling difficult to control. Spirality and bias are common problems in single jersey due to its inherent structural imbalance [6]. The spirality and bias of single jersey occurs when the wales and courses lean. Lau [25] determined that the effects of spirality results from yarn twist.

Jersey fabrics are commonly used in the production of hosiery, socks, t-shirts, and underwear. Hatch [7] stated that single jersey fabrics have good crosswise and lengthwise elongation, and the degree of elastic recovery varies with the fiber content and yarn structure. The fabric properties and parameters of a jersey structure are also dependent on the loop length [5].

2.5.1.2 Fleece (Laid in Yarn)

This is a fabric produced with two or three yarns of different counts with a knit construction being different from that of single jersey. Although it is named as lined fabric, in technology market it is known as two yarn fabric. The lining yarns (coarse yarns) are tied to the ground knit by the tuck movement alternately. The appearances of the face and reverse sides of the fabric are very different.

Coarse yarn is laid-in at the back of a plain-knitted fabric and the fabric is raised during finishing producing a fleecy appearance shown in Figure 2.36. Its presence tends to reduce the elasticity of the fabric. Such fabric is suitable for sweaters, tracksuits, dressing gowns, underwear, and children's wear.

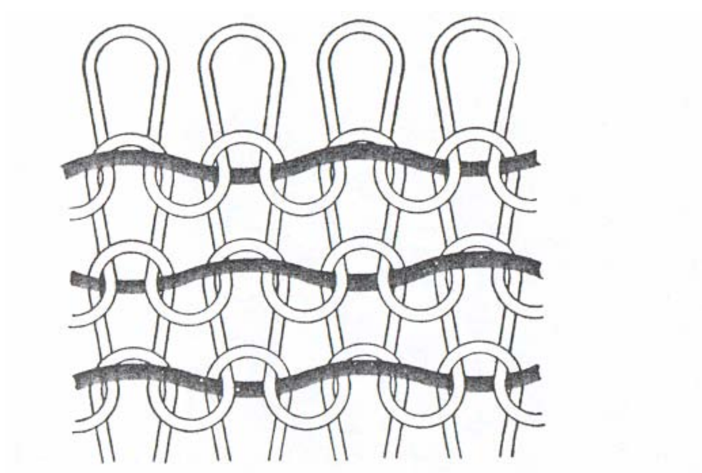


Figure 2.36 1-1 Laid in yarn [24].

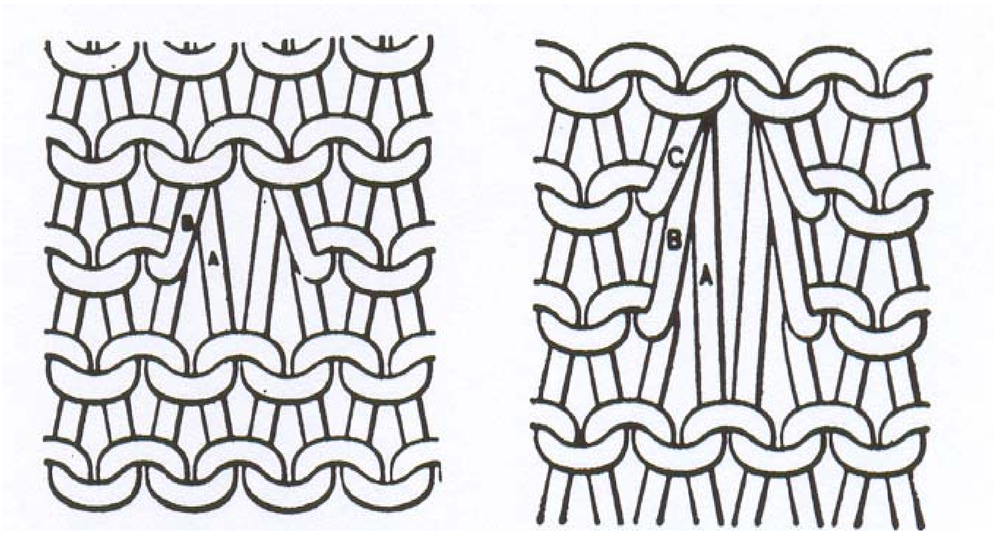
Two Thread Fleece: The ground is in the RL structure. It is produced on single jersey machines. The back side can be raised. Its lengthwise and widthwise elasticity are low. Its dimensional stability is superior to single jersey.

Three Thread Fleece: It is a kind of fabric produced with three kinds of yarns with different properties . Two yarns produce the ground knit and the third set produces the lining. This kind of fabric is produced on special machines. There are R loops on the front face, and loops forming the lining are seen on the back. Its stability is high with almost no elasticity. It is rather thick. Three thread fleece structures usually produce in heavy weights.

2.5.1.3 Tuck Lacoste

This stitch is produced by accumulating two or more loops on a needle and casting them off together. If the tuck stitch extends over more than one course in plain fabric, pronounced raised designs develop in the structure and these can be used to produce figured shapes. A single needle may be brought into tuck position at several feeds successively before it is placed in knit and cast-off positions and cleared. In that case, the needle will then take each fed yarn at tuck position and hold them all until it reaches the clearing feed.

a) Single tuck: A vertical stitch viewed from the double tuck stitch back of the fabric shown in Figure 2.37a. "A" viewed from the back is the held loop; "B" of the fabric.



(a) Single tuck (b) Double tuck

Figure 2.37 Tuck lacoste [27]

b) Double tuck: "A" is the tuck loop which held loop, "B" is not visible on the first tuck loop, and "C" is face of the fabric shown in Figure 2.37b. C is the second tuck loop.

Figure 2.37b illustrates a vertical double tuck stitch viewed from the back of the fabric. In this stitch there are two tuck loops and one held loop. The held loop is held two courses before it is cleared while the largest tuck loop "B" is held one course before it is cleared. When the tuck stitch contains more than one tuck loop, they may be numbered in the order of their formation. The longest tuck loop marked "B" would be No. I and the shortest one marked "C" would be No. 2 as shown in Figure 2.37b.

The longest loop of all remains the held loop. The longer each held and tuck loop remains on the needle, so the loop becomes the tighter and longer. The first reason of this is the surrounding fabric that is continually moving downward which elongates the held and tuck. Secondly, as the tuck needle is repeatedly drawn into cast-off position after it tucks, it steals yarn from the more relaxed adjacent jersey stitches.

The structure of this type of fabric is like as honeycomb. In double tuck lacoste the honeycomb effect is more visible than single tuck lacoste. Pique and lacoste are different knitting structures [28].

2.5.2 RR Structures

RR knitted fabric is produced on two needle beds facing each other on double bed machines. They have the same appearance both front and back. Fabrics are heavier than RL plain knitted fabrics.

2.5.2.1 Rib

The term “rib” covers a broad range of knitted structures from: 1x1, 2x1, 2x2. The simplest rib fabric shown in Figure 2.38 is a 1x1 and this is formed using 2 individual beds of needles whereby yarn passes from one bed to the other alternatively.

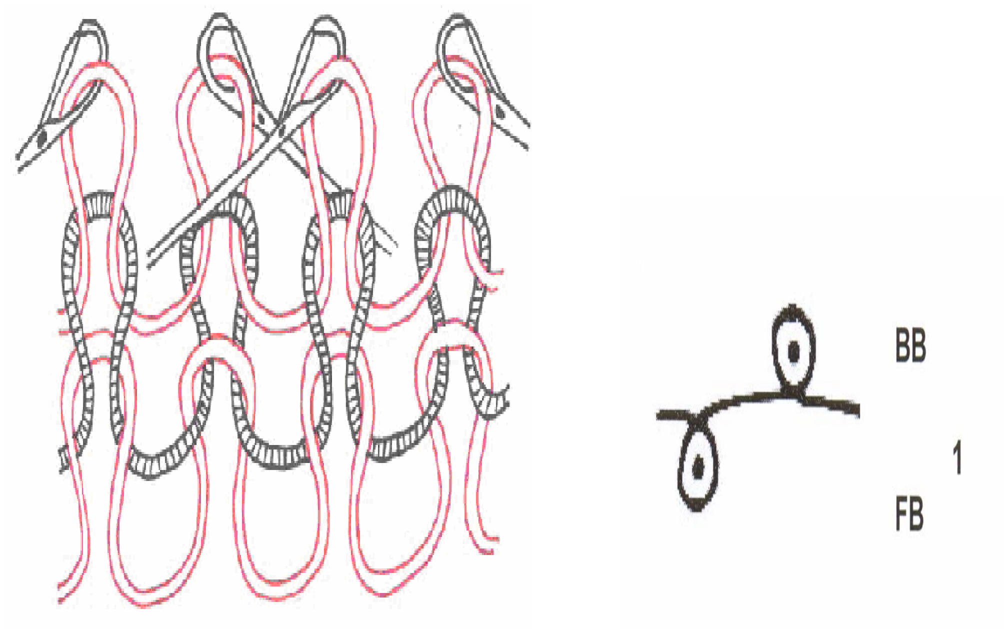


Figure 2.38 Schematic and diagrammatic view of 1x1 rib structure [8].

Rib fabrics are characterized as being bulky and very elastic widthwise, but a reduction in elasticity occurs by an increase in width of rib. A greater quantity of yarn is required in a rib fabric than in a plain fabric of similar general construction and width. Thus, they are heavier and slightly more expensive [3].

The most important property of rib fabric is its ability to stretch. The ease of bending wales in ribana results largely from high width extensibility. There is no spirality in the structure; however minimal skew is enough to easily distort the fabric.

Although knitted rib structures are widely used in outerwear, their main use is in providing welts, cuffs, and collars for garments with plain-knitted bodies and sleeves. There are two properties of 1 x1 rib fabric that make it particularly suitable for these trimmings. First, fabrics of this type are free from edge curling because they are balanced, unlike the unbalanced structure of single jersey that causes edges to curl. Secondly, rib fabrics readily extend in width and show immediate recovery from extension [4].

2.5.2.2. Interlock

Interlock illustrated in Figure 2.39 and Figure 2.40 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.

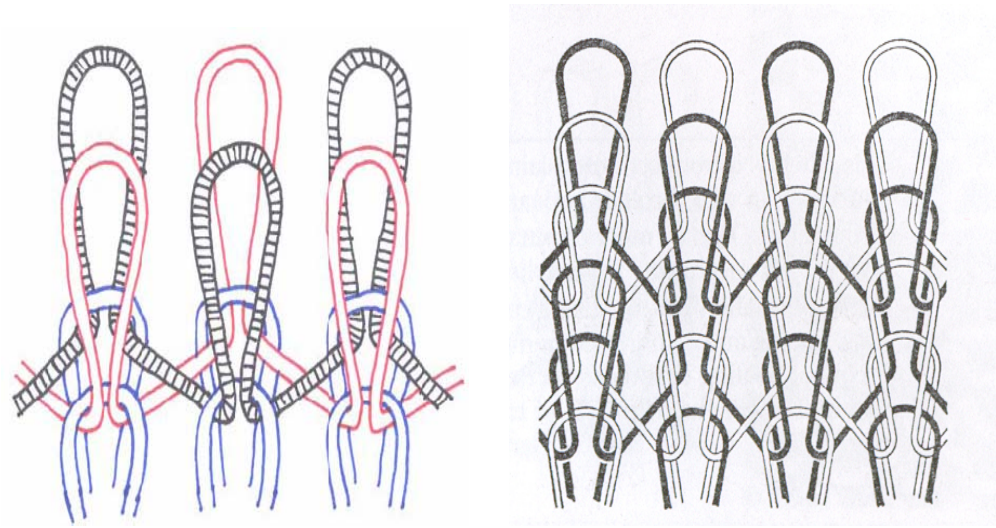


Figure 2.39 Interlock fabric constructions [8].

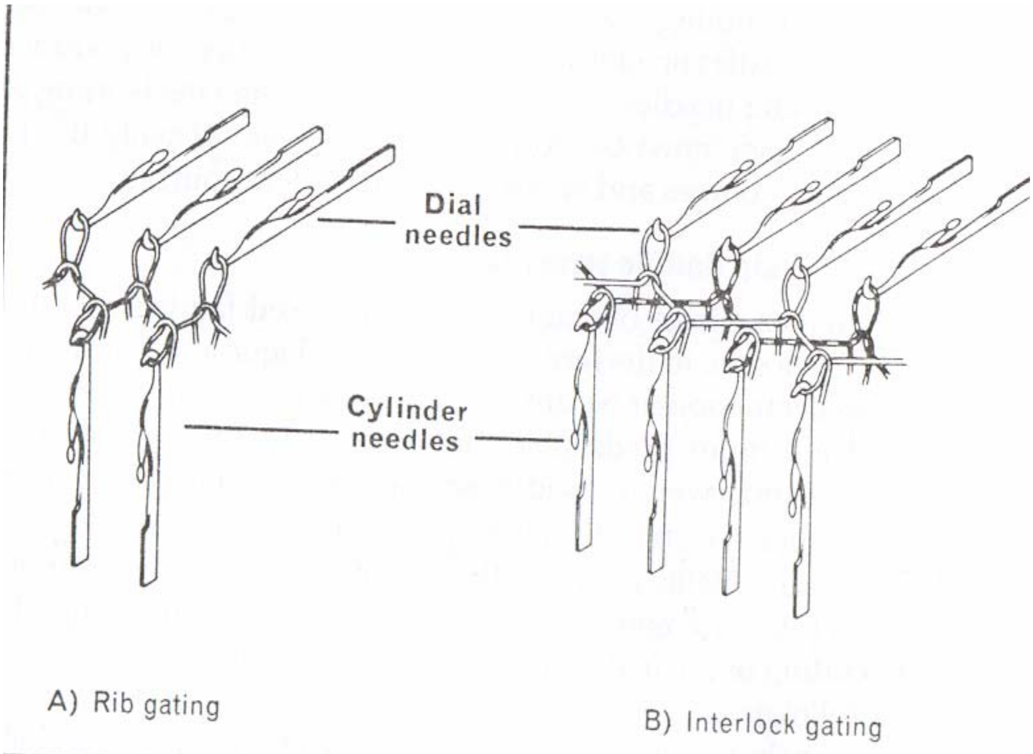


Figure 2.40 Rib and interlock gating [8].

As the knitting repeat is completed on double beds and is forming one row from two systems, the consumption of yarn is the highest. Interlock fabric has greater flexibility in the vertical direction compared to the horizontal direction. This kind of knitting has high size stability and high ability of maintaining its form. Its resistance to shrinkage is satisfactory.

When subjected to tension, the loops tend to travel from the edge. Since the number of loops on both front and back is equal, the fabric has a balanced structure. No rolling problem at edges exits as seen on the single bed produced fabrics. RR Interlock fabrics can only roll on the last knitted edge.

For the same stitch spacing interlock is heavier and thicker than rib knitting, but fine yarns are used in order to reduce the weight. The rate of production is slower than rib knitting and stitch patterning is more restricted.

The combination of two rib knitted structures in the interlock structure gives very little or no room at all for the wales or courses to close up. Therefore the interlock fabric shows very poor elastic properties in both directions [29].

2.5.3. LL Structures (Purl)

Purl fabrics shown in Figure 2.41 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 [23].

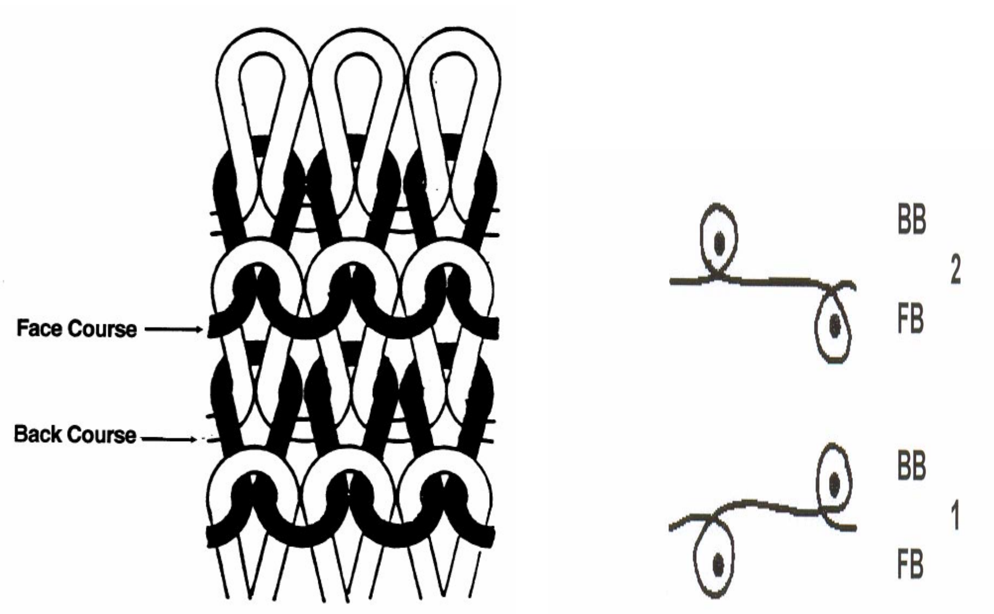


Figure 2.41 Purl fabric construction [8].

2.5.4. Comparison of RL-RR Fabrics

A comparison of four types is given in Table 2.2.

Table 2.2 A comparison of single jersey, 1x1 rib, interlock, d.t. lacoste

Structure	**Single Jersey**	**Ribana**	**Interlock**	**D.T. Lacoste**
Appearance	Loops on face	Both sides identical	Both sides identical	Loops on face
Extensibility-width	Less than 1 x1 rib	High	Higher than single jersey	Similar to s. jersey
Extensibility-length	Medium	Less than single jersey	Less than single jersey	Less than single jersey
Format	Tubular or open	Tubular or open	Tubular or open	Tubular or open
Needle setup	Cylinder bed needles	Rib gaiting, cylinder and dial beds used	Int. gaiting,	Cylinder bed needles
Stability	Instable	Stable	Stable	Instable
Bursting strength	Less than Ribana	Less than interlock	High	Lowest one because of pores
Fabric weight	Lowest one	Medium	High	Medium
Thickness	Due to single needle motion less than the others	Due to double needle motion higher than s.jerse	Due to double needle motion higher than s.jersey	Due to honeycomb effect highest one
Spirality	Due to inherent structural imbalance	Not a problem because structure is balanced	Not a problem because structure is balanced	Due to inherent structural imbalance
Bias/Skew	Occurs when fabric is allowed to relax, not present when fabric is on the machine. Due to number of feeders	Occurs when fabric is allowed to relax, not present when fabric is on the machine. Due to number of feeders	Occurs when fabric is allowed to relax, not present when fabric is on the machine. Due to number of feeders	Occurs when fabric is allowed to relax, not present when fabric is on the machine. Due to number of feeders
Curl	Curling due to unbalanced structure	No curling due to balance structure	No curling due to balanced structure	Curling due to unbalanced structure
Dimensional changes	Differential shrinkage due to bias	High and variable width shrinkage due to ease of distortion	High and variable width shrinkage due to ease of distortion	Differential shrinkage
Pilling	Medium	Less good than interlock	Poorest	Good

2.5.5. Loop Length and Tightness Factor Control

The fabric properties and parameters of a knitted structure are dependent on the loop length. When loop length is reduced, the fabric may appear tight and rigid. As the loop length increases, the fabric may appear looser and less rigid [5]. Loosely knitted fabrics are easily extensible and distorted; where as tightly knitted fabrics are more stable and less susceptible to distortions. Changes in loop length will cause an increase or decrease in the weight per unit area, which influences cost. Increasing the loop length will cause a decrease in the weight per unit area. Figure 2.42 illustrates how yarn size affects the tightness of a fabric.

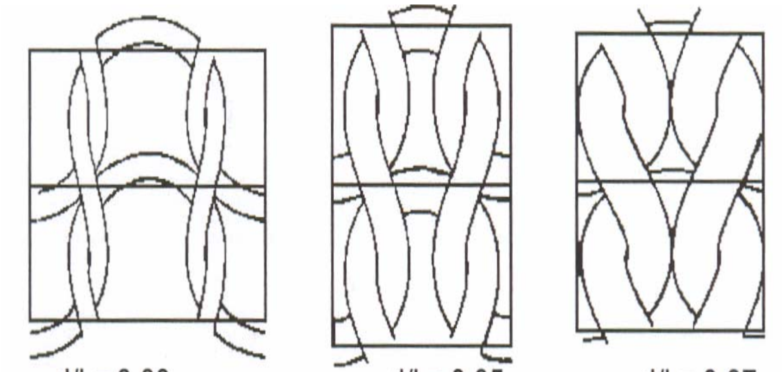


Figure 2.42 Effect of yarn size on tightness [30].

Cover factor is represented by the ratio d/l, where d is yarn diameter and l is the length of yarn in a loop suggested the use of a factor to indicate the relative tightness or looseness of plain weft knitted structure [6,30].

Tightness factor, K, can be defined as the ratio of area covered by yarn in one loop to area of one loop [31],

$$\frac{Lxd}{L^2} = \frac{1}{L \times \sqrt{N}} \qquad (2.1)$$

Yarn count, N, is related with tex.

$$Tex = \frac{1}{N} \qquad (2.2)$$

Then $K = \sqrt{Tex} / L$ (2.3)

Where Tex is yarn linear density and L is loop length in centimeters. The fabric dimensions depend on the tightness of the fabric. In fabrics knitted with the same loop length, the fabric dimensions vary as the count of the yarn [12,32].

The fabric dimensions associated with these loop shapes are represented by the rectangles that are unit cells of fabric. Hepworth [31] used single jersey structures that showed clearly the differences in shape of both the loops and the unit cells. Figure 2.44 illustrates the different states of jamming that can occur in relaxed fabrics.

The term “jamming,” occurs when courses or wales apply pressure at contact points. In Figure 2.44, it was determined that for d/l > 0.031, except for very slack fabrics and jamming is very low. In addition, there is jamming between wales in tight fabrics for which d/l > 0.06. High jamming values will produce a more rigid fabric than a fabric with less one. Therefore, fabric distortions are expected to occur in fabrics with less jamming or a low K value [31]. When a knitted fabric is extended along its wale-wise direction, the width in the course-wise direction will be reduced. However, this reduction is limited by jamming of the loop structure in the course-wise direction [32]. d/l ratio is known as cover factor [30].

Yarns of different counts knitted to the same loop length will display different physical properties, such as handle, drape, openness, permeability, etc. A fabric knitted from course yarn will be much more tightly knitted than would a fine one.

Gravas et al [12] describes that the tightness factor is a mean of assessing knitting performance. According to their experience, tightness factor has been experimentally proved that its values vary from 10 to 20 when the loop length is defined in cm. It has been found that the dynamic forces required to pull a wide range of yarn counts into a knitting loop are at a minimum when K is equal to 14.

Araujo et al.[32] studied about a theoretical model based on elastica theory and used for prediction of tensile properties of plain knitted fabrics. In their approach, they wanted to lead to a reduction in the need for destructive testing, especially in the case of knitted fabrics produced with high modulus yarns.

Different quality knitted fabrics from multi-feeder circular knitting machines are mainly produced by changing the stitch length. Altering the loop size (loop length) primarily requires adjustments the yarn delivery rate. The stitch cams also need to be adjusted to obtain a run-in yarn tension of 2-5 cN. Dias [33] stated that the measured loop length was changeable due to yarn winding tension.

2.5.6 Influence of Loop Length on Fabric Characteristics

Changes in loop length will cause an increase or decrease in the weight per unit area. Producing fabric with varying weight in this way may influence cost due to the amount of yarn consumed in fabric production and also influence fabric performance characteristics. Knit fabrics can be knitted loosely or tightly, but normally are knitted somewhere around the middle tightness depending on the end use of the product and the desired aesthetics. Each fabric has different extremes of knit tightness also dependent on the end use. In terms of distortion, greater fabric distortion is expected in looser fabric. Spirality and bias in single jersey cause fabric distortion, which is more apparent in loose knits. Wales should be completely vertical but spirality and extraneous forces can deform them.

The structure of a knitted fabric has large influence on the fabrics characteristics and can make them better or worse. Stitch density is directly related to the “loop length”. Loop length is the length of yarn contained in one complete knitted loop and it is adjusted on the knitting machine.

The effects of loop length [34];

- Stitch density/fabric density,
- Fabric weight and fabric cost,
- Fabric dimensions and panel size, shaped knitwear,
- Dimensional stability, relaxation and shrinkage,
- Physical performance, pilling, burst strength

Yarn size and volume can potentially have a direct influence on fabric thickness and resilience. If equal loop lengths are used, a yarn with a larger diameter, such as a bulkier yarn, would effectively make the fabric tighter. Tight fabric influences the amount of fabric movement due to less open space in the fabric for each loop while the loop length is the same, and the diameter of the yarn is varied.

CHAPTER 3

MATERIALS AND METHODS

3.1. INTRODUCTION

Eleven circular knitted fabrics have different placement and the number of tuck stitch and 1 single jersey fabric made of the same carded cotton yarn were produced for this study. The gray fabrics were then dyed to evaluate results on behalf of mills and consumers..

Test samples were knitted on circular knitting machines in Sanko Textile Mills and dyeing and finishing processes were performed in Soft Towel-Dying Mill.

The fabric performance tests were done with the testing instruments in Textile Engineering Department of University of Gaziantep and USAM.

3.2. MATERIALS

3.2.1. Fiber

100% Cotton fiber was used for this study. Cotton fiber was from Aegean and its identification chart was given in Table 3.1. Properties of CO were measured by HVI Spectrum.

Table 3.1 Fiber properties for the used yarn

Length (mm)	29,83
2,5% span length (mm)	28,37
Fineness (Micronaire)	4,5-4,9
Strength (g/tex)	32,2
Uniformity	83,3
Neps	89
SFI	5,9

3.2.2. Yarn

CO was spun by Ring-carded systems. All specifications of produced yarn were given in Table 3.2. Yarn count was measured by Zellweger Uster Autosorter and yarn strength was measured by Zellweger Uster Tensorapid Tester.

Table 3.2 Characteristics of yarn used for knitted samples

Count (Ne)	30/1
Unevenness (%)	12,2
Thin -50%	10
Thick +50%	180
Neps +200%	343
Hairiness	7
Yarn strength (Rkm)	16
Cv %	10
Elongation%	4,4
Yarn twist (T/m)	796
αe	3,7

3.2.3. Knitting Machine

All fabrics were knitted using the same Monarch single jersey machine which has a positive yarn feeding system. The machine specifications were given in Table 3.3.

Table 3.3 Machine specifications

Machine manufacturer	Monarch
Machine type	Circular knitting machine
Types of bed	Single bed
Fein (gauge)	28 E
Diameter (inch)	30
Number of needles	2582
Number of yarn feed system	84
Direction of machine rotation	Clock-wise (Z)
Knitting Speed (rpm)	30

3.2.4. Knitted Samples

Produced fabric types were collected in the groups given in below according to the placement of the tuck stitches in the fabric. Each fabric types also were numbered according to the number of the tuck stitches in their groups. Single jersey fabric was added to each group to compare each fabric type with single jersey fabric.

The number of tuck stitches of fabrics were determined by viewing the loop density of samples 1c and 4c which have the largest pattern.

84 courses x 4 wales= 336 loop

1) No zigzag type fabrics having tuck stitches and single jersey fabric
2) Zigzag type fabrics having tuck stitches and single jersey fabric
3) Lacoste type fabrics having tuck stitches and single jersey fabric
4) Honeycomb type fabrics having tuck stitches and single jersey fabric

3.2.4.1. 1st Group Samples (No zigzag type fabrics and single jersey fabric)

There are 3 fabric types and single jersey in this group.

1-a; has 4 tuck stitch in the same needle (Figure 3.1).
1-b; has 2 tuck stitch in the same needle (Figure 3.2).
1-c; is combination of (1-a) has 54 course and single jersey has 30 course (Figure 3.3).
Single jersey; no has tuck stitch (Figure 3.4).

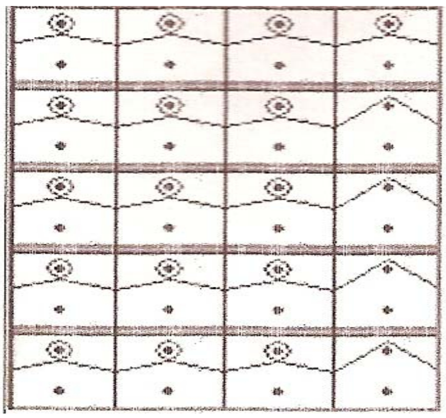


Figure 3.1 Sample **1-a**

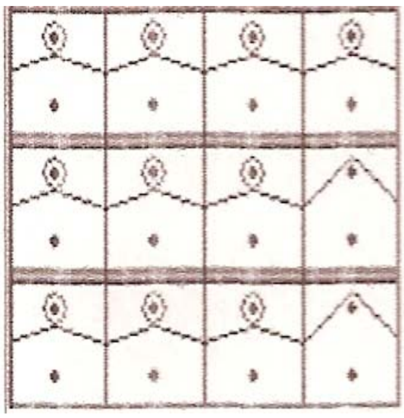


Figure 3.2. Sample **1-b**

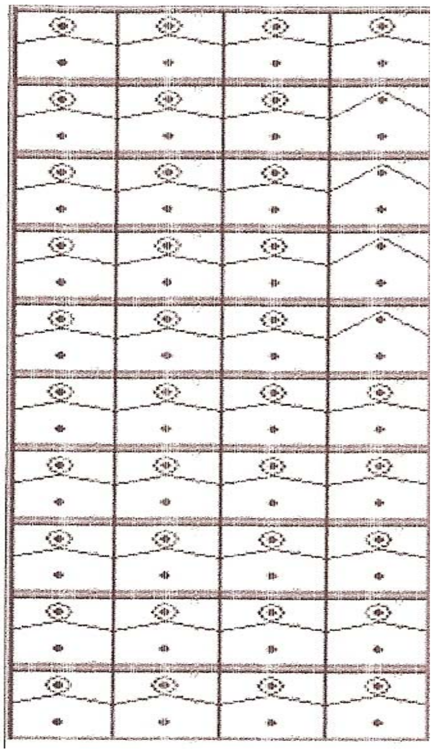


Figure 3.3 Sample **1-c**

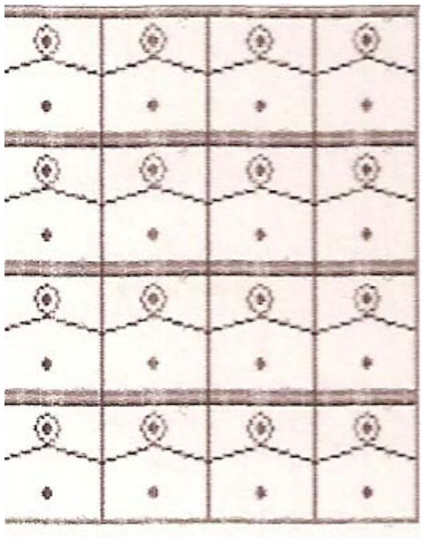


Figure 3.4 **Single jersey**

3.2.4.2. 2nd Group Samples (Zigzag type fabrics and single jersey fabric)

There are 2 fabric types and single jersey in this group.

2-a; has 2 tuck stitches in the adjacent needles for all courses (Figure 3.5).

2-b; has 2 tuck stitches in the adjacent needles for 1st and 2nd courses and then 1 tuck stitch in the other needles for 3rd and 4th courses (Figure 3.6).

Single jersey; no has tuck stitch

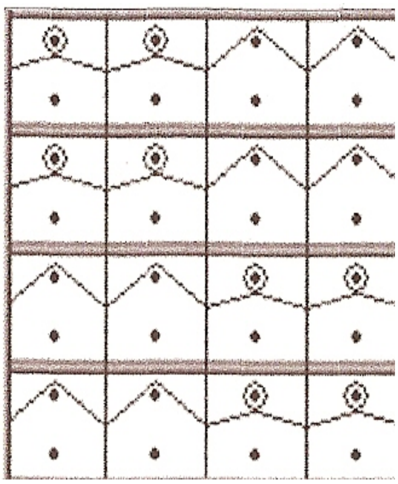


Figure 3.5 Sample **2-a**

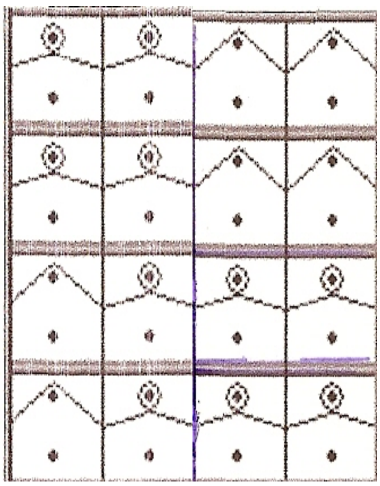


Figure 3.6 Sample **2-b**

3.2.4.3. 3rd Group Samples (Lacoste type fabrics and single jersey fabric)

There are 3 fabric types and single jersey in this group.

3-a; has 2 tuck stitch in the same needle and no single jersey course (Figure 3.7).
3-b; has 2 tuck stitch in the same needle and 1 single jersey course (Figure 3.8).
3-c; has 1 tuck stitch in the same needle and 1 single jersey course (Figure 3.9).
Single jersey; no has tuck stitch

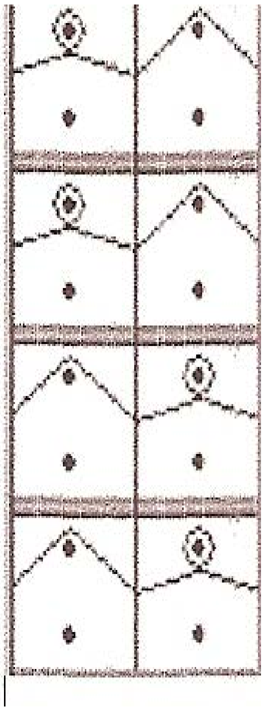


Figure 3.7 Sample **3-a**

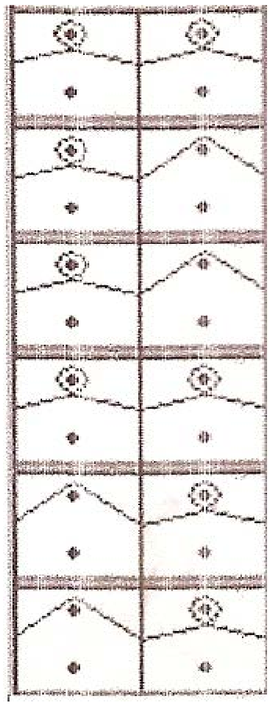


Figure 3.8 Sample **3-b**

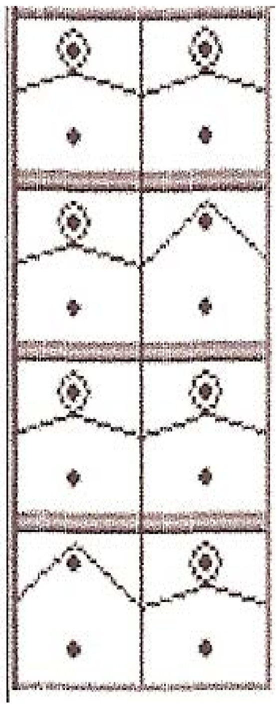
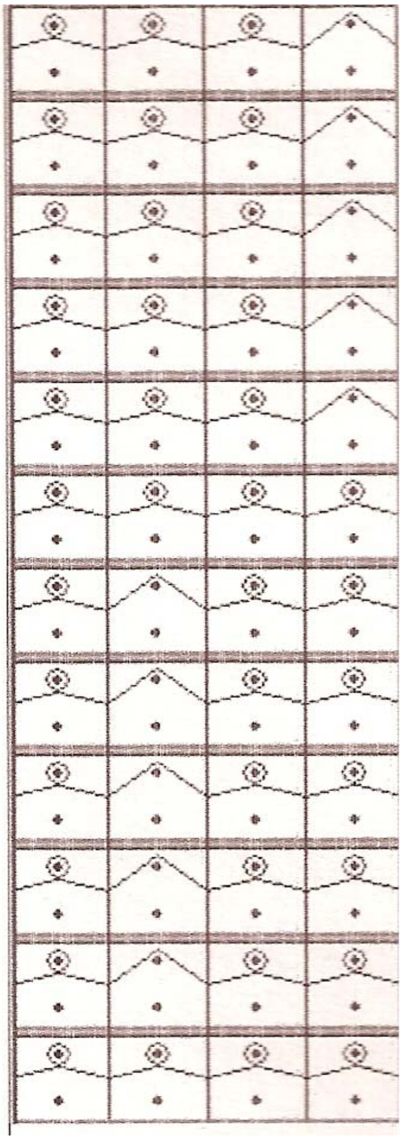


Figure 3.9 Sample **3-c**

3.2.4.4. 4th Group Samples (Honeycomb type fabrics and single jersey fabric)

There are 3 fabric types and single jersey in this group.

4-a; has 5 tuck stitch in the 1 same needle and 1 single jersey course (Figure 3.10).
4-b; has 4 tuck stitch in the 1 same needle and 2 single jersey courses(Figure 3.11).
4-c; is combination of 4-b has 48 courses and single jersey has 36 courses.
Single jersey; no has tuck stitch



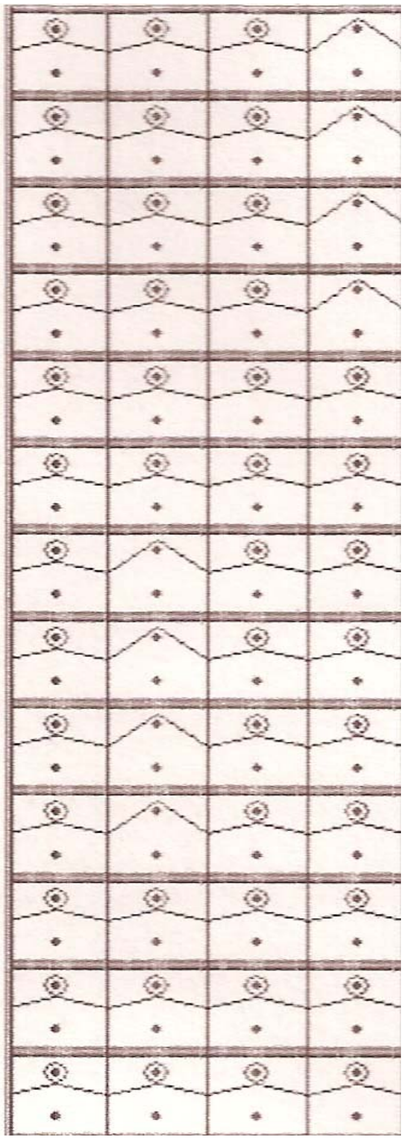


Figure 3.10 Sample **4-a** Figure 3.11 Sample **4-b**

3.2.5. Dyeing and Finishing

The knitted samples were firstly kiered and then dyed in finishing department of Soft Towel-Dyeing Mill in Gaziantep. After dyeing, samples were washed. Drying were made in dryer, but samples were not sanforized to measure dimensional change of fabrics, correctly.

Phases of finishing process : Dry tearing→ Kiering→ Dying→ Washing→ Wet tearing→ Drying

Kiering, dying and washing recipes were given in Tables 3.4-3.6.

Table 3.4 Kiering recipe

Cottoclarin OK (wetting agent)	0.6 g/l
Mollan 129 (ionizor)	0.5 g/l
Caustic	1 g/l
Hydrogenperoxide	1 g/l
Baystabil DB-T (stabilizator)	0.5 g/l
Rogly SI Flus (antiperoxide)	0.2 g/l
Acetic acid	0.5 g/l

Table 3.5 Dying recipe

Cibacron Blue FN-R (colour agent)	0.01 %
Mollan 129 (ionizor)	0.5 g/l
Imacol C-2G (ionizor)	0,3 g/l
Sodium sulphate	10 g/l
Sodium carbonate	10 g/l

Table 3.6 Washing recipe

Acetic acid 80%	0.2 g/l
Acetic acid 80%	0.5 g/l
Locanit SW (soap)	0.2 g/l
Acetic acid 80%	0.3 g/l
Tubingal KRE (softener)	3 g/l

3.3. METHODS

All test methods were applied by two main groups; gray and dyed. The physical properties; weight in square meter, number of courses and wales, loop length and fabric thickness and performance properties; abrasion resistance, pilling resistance, dimensional stability, bursting strength, spirality were determined for this study.

Prior to marking and measuring, the samples were conditioned test specimens as directed in ASTM Practice D 1776, Conditioning for Testing. Each specimen was conditioned at least 4 h in an atmosphere of 20 ± 2^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 [35].

3.3.1. The Determination of Physical Properties of Knitted Samples

3.3.1.1. The Determination Method of Fabric Weight

Fabric weight was determined according to TSE EN 12127 April 1999; "Textiles-Fabrics-Determination of mass per unit area using small samples". The samples were cut as 10 cm^2 from six different places on the same sample. These samples were weighted by sensitive scale and the average of six weights was calculated. This value was multiplied by 1000 to find the weight of fabric 1 m^2 [36].

3.3.1.2. The Determination Method of Fabric Wales and Courses

The number of wales and courses were determined according to TSE EN 14971 July 2006; " Textiles- Knitted Fabrics- Determination of number of stitches per unit length and unit area." The numbers of courses and wales in 1 cm length of fabric were found with the help of a magnifying glass for every sample at ten different places and the average values were calculated [37].

3.3.1.3. The Determination Method of Loop Length

Loop length was measured by using manual method for all loops. For this purpose, 100 loops were counted on fabric and measured under 10g stretched force. The average value of 100 loop length (LFA) was divided by 100 to obtain the individual loop length. Measurements were repeated ten times and then the average of these 10 measurements was calculated.

Smirtiff [1] stated that it did not give an extra extension to deknitted yarn by using 10g stretch force for reforming the curl on deknitted yarn.

Physical properties of knitted samples are given in Table 3.7.

Table 3.7 Physical properties of knitted samples

Fabric Code	Number of tucks	Loop Length (L) (mm)	Tightness Factor (1/L) (K)	Number of Course/cm		Number of Wales/cm		Weight (g/m^2)		Width (cm)	
				Gray	Dyed	Gray	Dyed	Gray	Dyed	Gray	Dyed
1-a	67	3,01	0,332	20	19,8	11	11,7	137	152	114	112
1-b	56	2,7	0,37	17	17,5	11,5	12,5	138	159	112	107
1-c	43	3,01	0,332	20	18,5	11,5	13	135	144	112	102
2-a	168	2,26	0,442	15	14	12	14	137	166	113	95
2-b	126	2,54	0,393	13,5	13,5	11	12,6	137	161	113	104
3-a	168	2,6	0,384	15	15,5	10,5	11,7	145	174	116	113
3-b	112	2,65	0,377	17	17,5	11	11,5	168	184	117	118
3-c	84	2,6	0,384	14	14,5	11	12	142	180	112	108
4-a	70	3,15	0,317	13	14,5	12	11,5	132	150	110	113
4-b	56	2,7	0,37	17	17,5	11,5	13,5	146	172	110	95,5
4-c	32	2,7	0,37	17,5	18	12,5	14	137	168	110	92
single jersey	0	2,7	0,37	21	20	12,5	15,5	130	155	107	87

3.3.1.4. The Determination Method of Fabric Thickness

Fabric thickness was determined according to TS 7128 EN ISO 5084; " Textiles-Determination of thickness of textiles and textile products" [38].

Apparatus: All instruments for measuring fabric thickness consist of a flat metal surface (the anvil) and a presser foot, usually circular, of known area smaller than the anvil. The instrument must provide the gradual lowering of the presser foot onto the anvil and reading the distance between the two to the nearest 0.001 inch or 0.02 millimeter.

Principle: A randomly selected specimen, at least 20 percent larger than the area of the presser foot, is placed on the anvil, and the presser foot is lowered into contact with the top surface of the fabric. Then the thickness is read from the dial of the instrument [38].

After conditioning, ten measurements were taken for each sample by the Paramount thickness measuring device (Figure 3.12). Then the average of these ten measurements was taken.

Figure 3.12 Paramount thickness measuring device

3.3.2. The Determination of Performance Properties of Knitted Samples

3.3.2.1. Abrasion Resistance Measurements and Calculations

Abrasion resistance of specimens was measured according to the TS EN ISO 12947-1 " Textiles- Determination of the abrasion resistance of fabrics by the Martindale method- Part-1: Martindale abrasion testing apparatus" and TS EN ISO 12947-3 "Textiles- Determination of the abrasion resistance of fabrics by the Martindale method- Part-3: Determination of mass loss" [39, 40].

Apparatus: The Martindale abrasion instrument (seen in Figure 3.13) is a British instrument that can be used for woven, knit, or nonwoven fabrics. This apparatus is designed to give a controlled amount of abrasion between fabric surfaces at comparatively low pressures in continuously changing directions. The results of this test should not be used indiscriminately, particularly not for comparing fabrics of widely different fiber composition or construction. In the test, circular specimens are abraded under known pressure on an apparatus, which gives a motion that is the resultant of two simple harmonic motions at right angles to one another. The fabric under test is abraded against a standard fabric. Resistance to abrasion is estimated by visual appearance or by loss in mass of the specimen [39, 40].

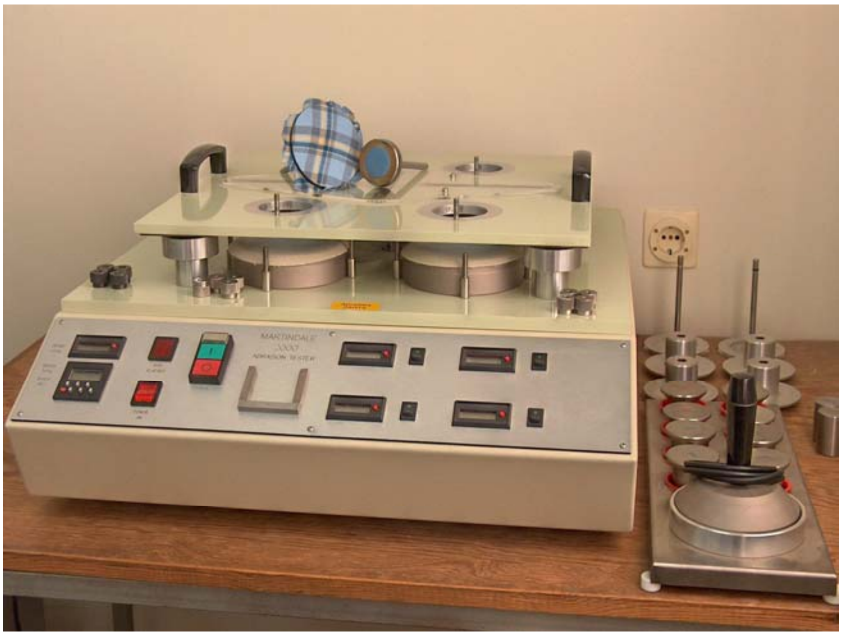


Figure 3.13 The Martindale Abrasion Tester 2000

Principle: Four specimens each 38 mm in diameter are cut using by the appropriate cutter. They are then mounted in the specimen holders with a circle of standard foam behind the fabric being tested. It is important that the mounting of the sample is carried out with the specimens placed flat against the mounting block [39, 40]. A spindle is inserted through the top plate and the correct weight (usually of a size to give a pressure of 12 kPa but a lower pressure of 9 kPa may be used if specified) is placed on top of this. The standard abradant should be replaced at the start of each test and after 50,000 cycles if the test is continued beyond this number. While the abradant is being replaced it is held flat by a weight as the retaining ring is tightened. Behind the abradant is a standard backing felt which is replaced at longer intervals [39,40].

All specimens were controlled in 2500, 5000, 7500 and 10000 cycles. The tests were stopped at 10000 movements. At the end of each cycles, the percentage mass loss of the samples were determined and reported for abrasion resistance. The experiment was repeated four times and the average was calculated.

3.3.2.2. Dimensional Stability Measurements and Calculations

The dimensional stability of specimens was determined according to AATCC Test Method 135 (1995)- “Dimensional Changes in Automatic Home Laundering of Woven and Knit Fabrics” [41].

Apparatus: The apparatus and materials used in this study are;

- Automatic washing machine
- Automatic tumble dryer
- 1993 AATCC standard reference detergent
- Ballast of 92x92 cm hemmed pieces of bleached cotton sheeting (wash load ballast type 1)
- Indelible ink marking pen for use with suitable rule
- Measuring devices

Marking of Specimens: This procedure was made as determined TS 4073- EN ISO 3759 “Textiles preparation, marking and measuring of fabric specimens and garments in tests for determination of dimensional change” [42].

The recommended sample size is 500mmx500mm and for routine works a minimum sample size of 300mmx300mm is considered sufficient. In this study specimens were prepared as 300mmx300mm. Six marks were made in each direction a minimum 350mm apart and at least 50mm from all edges on each sample and then the average of these 6 measurements was calculated.

Testing: After all samples were conditioned in the standard atmospheric conditions, they were washed and dried as explained in AATCC Test Method 135. Last and the most important procedure wsa laundering in determining dimensional changes. Preferred washing machine was home type and programmer is B; washing process was 2 hours and 15 minutes and the temperature is 60º C. Washed samples were dried by a tumble dryer for 70 minutes on 70º C. These laundering properties were chosen because the single jersey fabrics and the other samples are generally used as under clothes or outerwear clothes and many people wash and dry these clothes under these laundering conditions. It was important to investigate the home laundering effect on the dimensional stability [43].

After washing and drying, each test specimen was conditioned, again and then laid without tension on a flat smooth horizontal surface. The distance between each pair of bench marks were measured and recorded.

5 laundering were made for all samples. After each laundering, measurings were repeated and recorded. Calculation of dimensional stability for each direction was done according to following equations;

$$\% DC = \frac{(B - A)}{A} * 100 \qquad (3.1)$$

DC : Dimensional change

A : Original dimension

B : Final dimension

Length and width changes were calculated separately. The increase in the dimension -extension- is reported as a positive "+" percentage, while the decrease in the dimension –shrinkage- is reported as a negative number "-" [44].

3.3.2.3. Bursting Strength Measurement

EN ISO 13938-2 “Textiles – Bursting Properties of Fabrics – Part 2: Pneumatic Method for Determination of Bursting Strength and Bursting Distension” was used in this experimental study [45]. James Heal Truburst bursting strength test machine is shown in Figure 3.14.

Figure 3.14 James Heal Truburst bursting strength test machine

This standard describes a pneumatic pressure method for the determination of bursting strength and bursting distension of textile fabrics. For the purposes of this standard the following definitions are applied:

Test area: Area of the test specimen within the circular clamping device.

Bursting Pressure: Maximum pressure is applied to a test specimen clamped over an underlying diaphragm until the test specimen ruptures.

Bursting Strength: is obtained by subtracting the diaphragm pressure from the mean bursting pressure.

Bursting Distension: Expansion of a test specimen at the bursting pressure.

Height at Burst: Distance between the upper surface of the test specimen before distension and the top of the test specimen at the bursting pressure.

Time to Burst: Time taken to distend a test specimen to burst.

Principle: A test specimen is clamped over an expansive diaphragm by means of a circular clamping ring. Increasing compressed air pressure is applied to the underside of the diaphragm, causing distention of the diaphragm and the fabric. The pressure is increased smoothly until the test specimen bursts. The bursting strength and bursting distention are determined.

The apparatus shall be capable of producing an increase in air pressure to achieve a testing time to burst of (20±5)s. Height at burst up to 70 mm shall be indicated with an accuracy of ±1mm. A test area of 50 cm² (79,8 cm diameter) was used.

Five measurements were taken for each sample. Then the average of these 5 measurements was taken.

3.3.2.4. Pilling Measurements

TS EN ISO 12945-2 "Textiles – Determination of Fabric Propensity to Surface Fuzzing and to Pilling – Part 2: Modified Martindale Method" was used to investigate the pilling resistance of specimens [46]. This test method covers the determination of the resistance to the formation of pills and other related surface chances on textile fabrics using Martindale tester.

Apparatus: The Martindale Tester 2000.

Principle: Pilling and other changes in the surface appearance such as fuzzing, that occur in normal wear are simulated on a laboratory testing machine. A pair of circular specimens from each swatch is cut in the laboratory sample with one of each pair of specimens being 38mm in diameter and other 140mm in diameter.
Fabrics are mounted on the Martindale Tester and the face of the test specimen is rubbed against the face of the same mounted fabric in the form of a geometric figure called lissajous movement. The degree of fabric pilling or surface appearance change produced by this action is evaluated by comparison of the test specimen with visual standards (photographs of fabrics) showing a range of pilling resistance. The

observed resistance to pilling is reported. But, pilling resistance of samples were evaluated as counting pills/cm^2 in this study.

All specimens were controlled in 125, 500, 1000 and 2000 cycles. The tests were stopped at 2000 cycles. Pills/cm^2 on the specimens was counted in each cycle. The experiment was repeated nine times and the average was calculated.

3.3.2.5. Spirality Measurements

Spirality of specimens was determined according to IWS 276 test standard method. This method covers to measure the angle of spirality in the structure .

Principle: According to this method 10 different places were chosen for each specimen, first a wale was marked by a pen and the course linked wale was then marked. By using a protractor the angle different from the normal of the wale was measured. (Figure 3.15 and 3.16) [47]. Then the average was calculated.

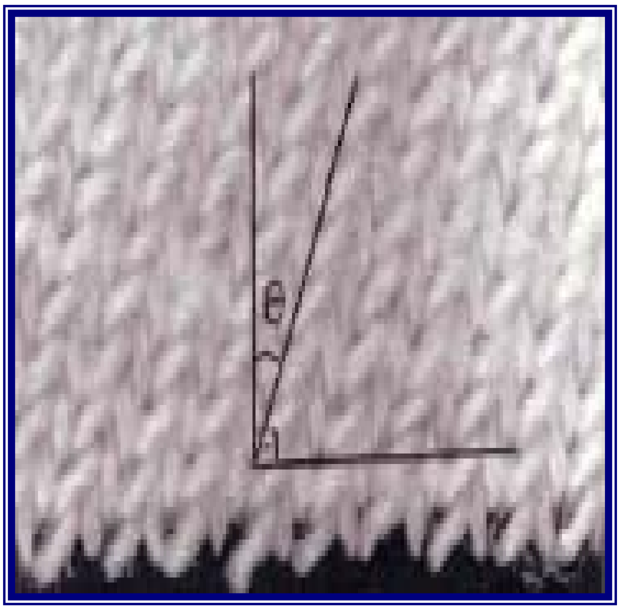


Figure 3.15 Spirality angle

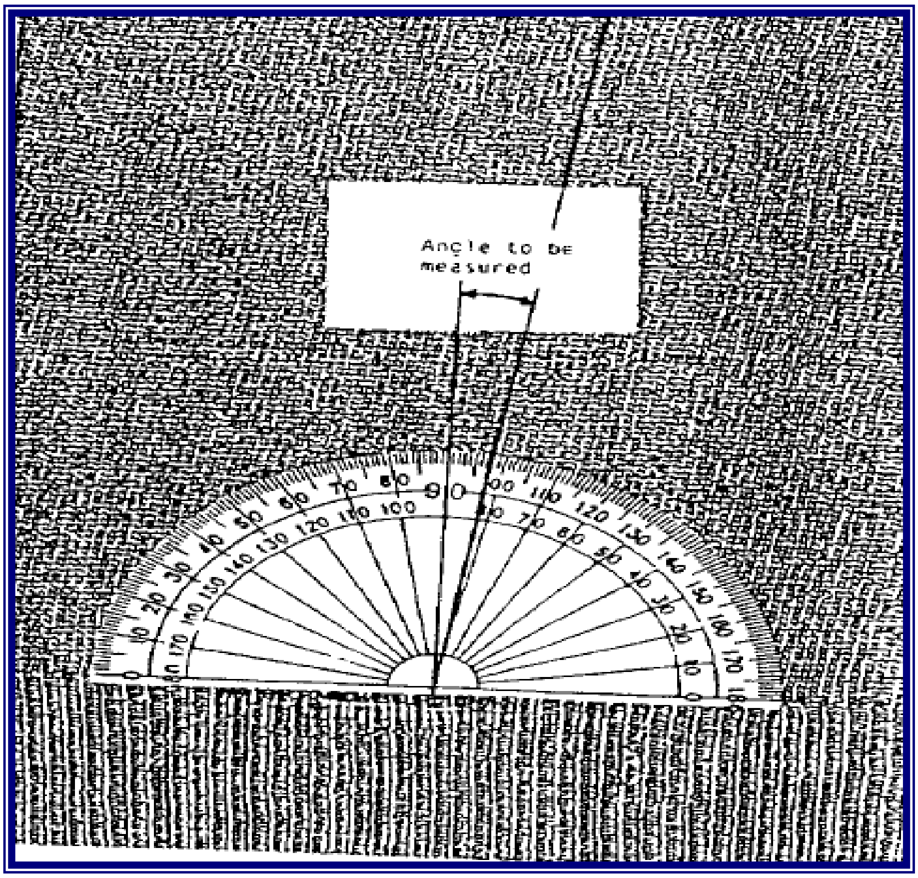


Figure 3.16 Measurement of spirality angle

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The effects of the placement and the number of tuck stitches, the loop length and the dyeing process were tested on the performance properties and the statistical analysis of the test results were discussed in this chapter.

ANOVA was performed on the experimental results of the samples to point out the statistical importance and the effects on performance properties and also Pearson correlation analysis was performed to indicate the relationship between the number of tuck stitches and the performance properties according to the statistical approach. Moreover, the regression equations were derived to obtain the important relationships between the correlation analysis results. For this aim the statistical software package, SPSS 13.0 was used to interpret the experimental results. All test results were assessed at $P \leq 0.05$ and $P \leq 0.01$ significance level.

ANOVA, CORRELATION and REGRESSION results on the performance properties were given in Appendix A.

4.2 DIMENSIONAL STABILITY

The test results were plotted on the figure separately for each sample group. Gray and dyed samples results versus the number of tuck stitches were shown in the figures.

The experimental studies on the dimensional stability for each laundering were given in Appendix B.

Table 4.1 shows the shrinkage and the extension values of samples obtained from the dimensional stability tests after 5 laundering.

Table 4.1 Shrinkage and extension values of samples after 5 laundering

Samples		Single jersey	1-a	1-b	1-c	2-a	2-b
Lengthwise (%)	Gray	-6,21	-29,33	-27,49	-20,21	-23,77	-29,05
	Dyed	-2,55	-14,1	-9,05	-11,71	-11,16	-13,83
Widthwise (%)	Gray	-19,83	0,16	-9,83	-20,21	-9,99	-2,38
	Dyed	-1,61	7,27	-2,71	5,49	-2,99	7,22
Samples		**3-a**	**3-b**	**3-c**	**4-a**	**4-b**	**4-c**
Lengthwise (%)	Gray	-26,7	-25,55	-28,27	-26,88	-23,77	-8,83
	Dyed	-14,27	-14,83	-13,77	-14,88	-12,16	-8,38
Widthwise (%)	Gray	1,83	-2,83	-4,94	6,94	-17,1	-20,49
	Dyed	-7,05	5,99	4,49	14,77	3,22	-2,71

4.2.1 Dimensional Stability for Lengthwise

The shrinkage values of gray samples decrease in the lengthwise direction while the number of tuck stitches decreases as shown in Figure 4.1. The tuck stitch gives effect of widening to the weft knitted fabrics [6]. When the widthwise shrinkage decreases or the widthwise extension increases the lengthwise shrinkage increases in the knitted fabrics.

It is also seen that the shrinkage values of dyed samples are lower than the shrinkage values of gray samples, for the dimensional stability values for the lengthwise are affected by the take-down tension [48]. In addition, the effect of take-down tension has not occur in fabrics having full relaxation. Dyed fabrics are fully relaxed fabrics, so this tension effect is not seen on dyed fabrics.

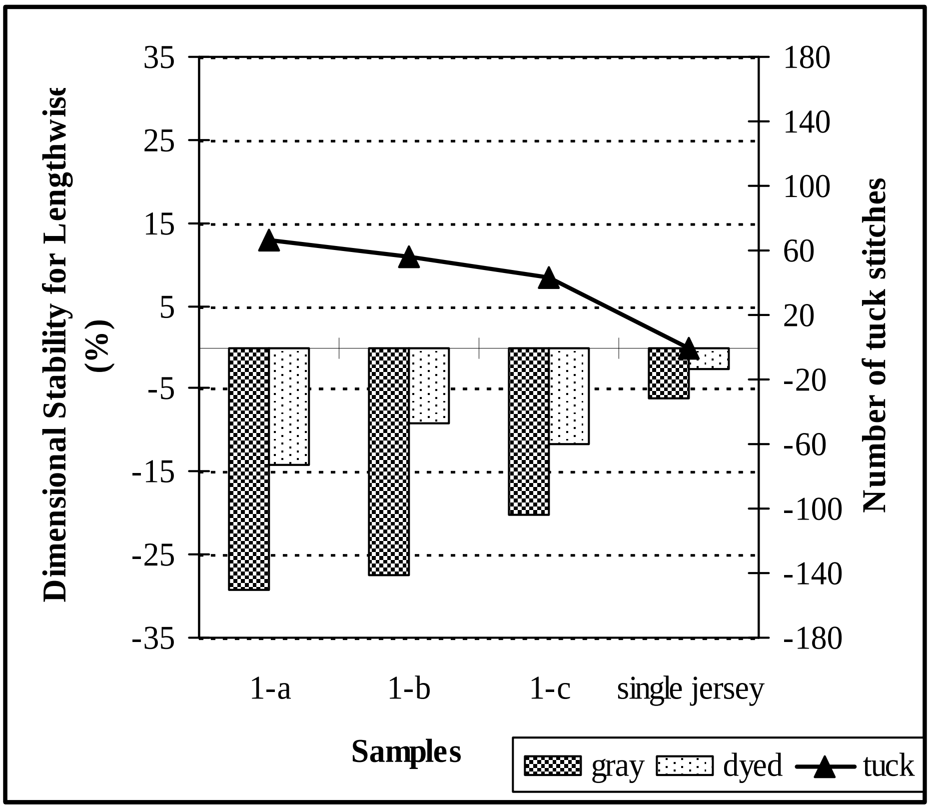


Figure 4.1 Dimensional stability of the 1st group after 5 laundering

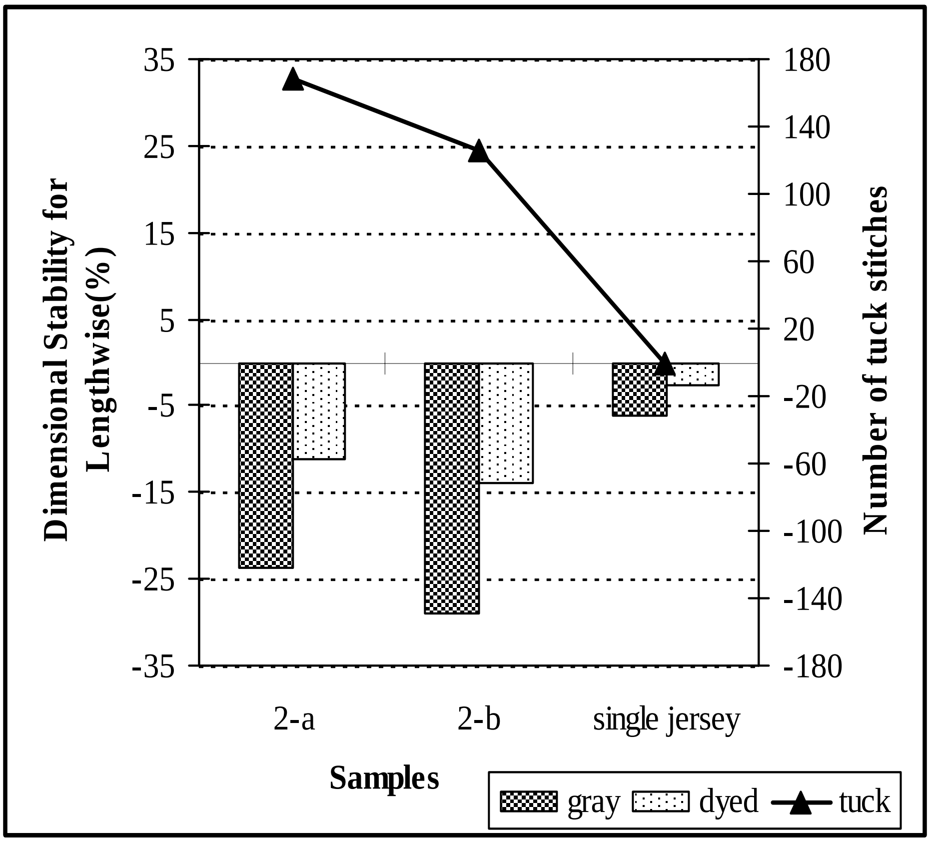


Figure 4.2 Dimensional stability of the 2nd group after 5 laundering

Although sample 1-c has the lower number of tuck stitches than sample 1-b, the lengthwise shrinkage value of sample 1-c is higher than the lengthwise shrinkage value of sample 1-b in both gray and dyed fabrics, since sample 1-c has higher number of tuck stitches in the same needle. Finally, single jersey fabric has the lowest shrinkage value in both gray and dyed samples because of having no the tuck stitch.

According to Figures 4.2, 4.3 and 4.4; the shrinkage values of samples having the tuck stitches are higher than the shrinkage value of single jersey, and also the shrinkage values of dyed samples are lower than the shrinkage values of gray samples on account of the same reasons as seen in the 1st group.

It is observed that sample 2-b has the higher lengthwise shrinkage value than sample 2-a as different from the expected result. The reason of this is that the loop length of sample 2-b is higher than the loop length of sample 2-a. Therefore, increase on the loop length of the knitted fabrics simply causes an increase on the lengthwise shrinkage. It is also seen from Figure 4.3 that the shrinkage values of samples 3-a, 3-b and 3-c having the tuck stitches are very close to each other for the number of tuck stitches in the same needle is close in these samples.

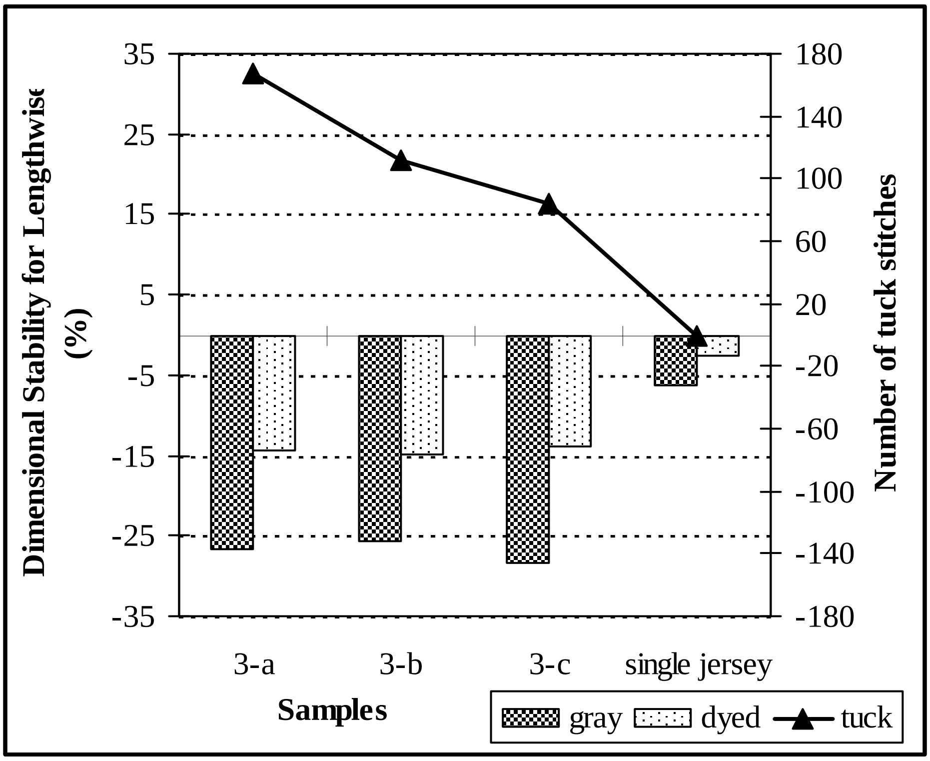


Figure 4.3 Dimensional stability of the 3rd group after 5 laundering

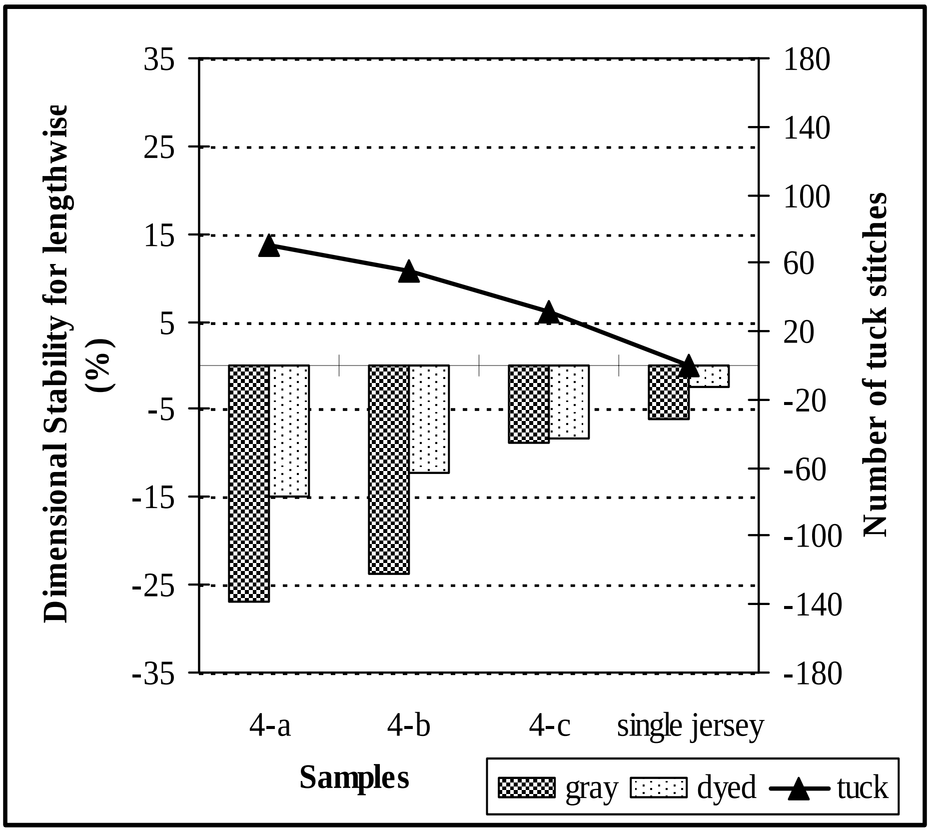


Figure 4.4 Dimensional stability of the 4th group after 5 laundering

4.2.2 Dimensional Stability for Widthwise

The tuck stitch gives the effect of widening on the weft knitted fabrics [6]. Thus it is usually seen that the widthwise shrinkage values are lower than the lengthwise shrinkage values in the weft knitted fabrics having the tuck stitch. On account of this, it can be seen the less shrinkage values or the extension values for the widthwise direction. Furthermore, the extension is especially seen in fully relaxed fabrics. Because of this reason the extension values of dyed samples are more than the extension values of gray samples.

In Figure 4.5; it is seen that sample 1-a having the highest number of tuck stitches has the lowest widthwise shrinkage value for gray samples. It is also seen that the widthwise shrinkage values of single jersey and combinated sample 1-c are very close. Consequently, as the number of tuck stitches decreases, the widthwise shrinkage values increase for gray samples.

For dyed samples, it is observed that there is an extension in samples 1-a and 1-c. On the contrary, there is a shrinkage in sample 1-b and single jersey for the widthwise.

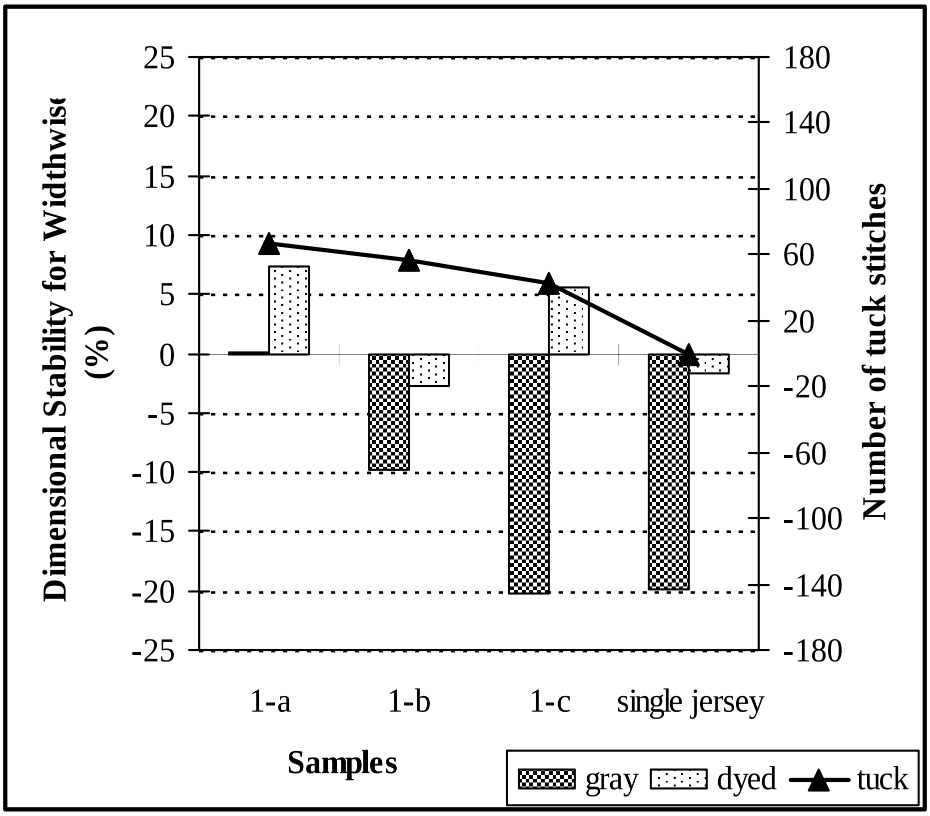
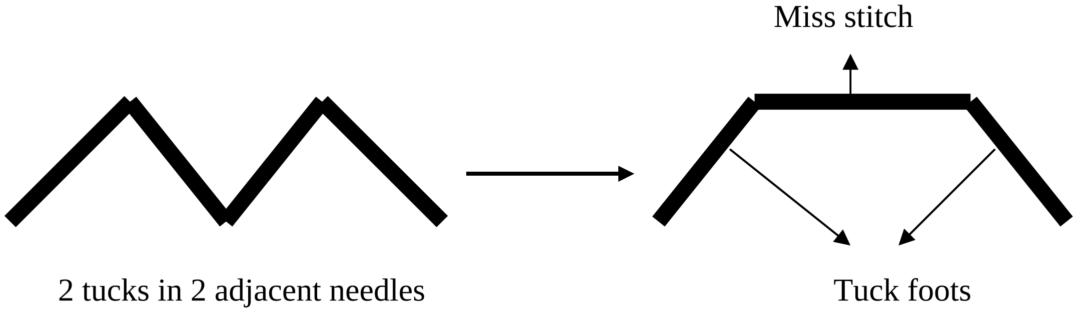


Figure 4.5 Dimensional stability of the1st group after 5 laundering

The reason of this situation is that samples 1-a, 1-c have the higher number of tuck stitches in the same needle (4 tucks) than sample 1-b (2 tucks). As the final result, it is seen that the dimensional change values of dyed samples are lower than the dimensional change values of gray samples, for dyed fabrics are fully relaxed.

According to Figure 4.6; the widthwise shrinkage values of samples 2-a and 2-b having the tuck stitch are lower than the widthwise shrinkage value of single jersey for gray samples. It is also interesting that the widthwise shrinkage value of sample 2-a is higher than the widthwise shrinkage value of sample 2-b. This situation can be explained that the miss stitch effect on sample 2-a is more than the miss stitch effect in sample 2-b. So an increase on the number of tuck stitches in adjacent needles leads to the tuck stitch turning to the miss stitch. Moreover, the miss stitch gives shrinking to the weft knitted fabrics [6]. In sample 2-a, there is a miss stitch effect in all of four courses. On the contrary, there is a miss stitch effect for two courses in sample 2-b, so it is determined that the widthwise shrinkage value of sample 2-a is higher than the widthwise shrinkage value of sample 2-b by reducing of the tuck stitch effect.

When there are the tuck stitches in two or more adjacent needles the tuck stitch gives the effect of miss stitch as seen in below.



For dyed samples, there is an extension value in sample 2-b and a shrinkage value in sample 2-a and single jersey, and also the widthwise shrinkage values of dyed samples are lower than the widthwise shrinkage values of gray samples because of the same reasons as mentioned in the 1st group.

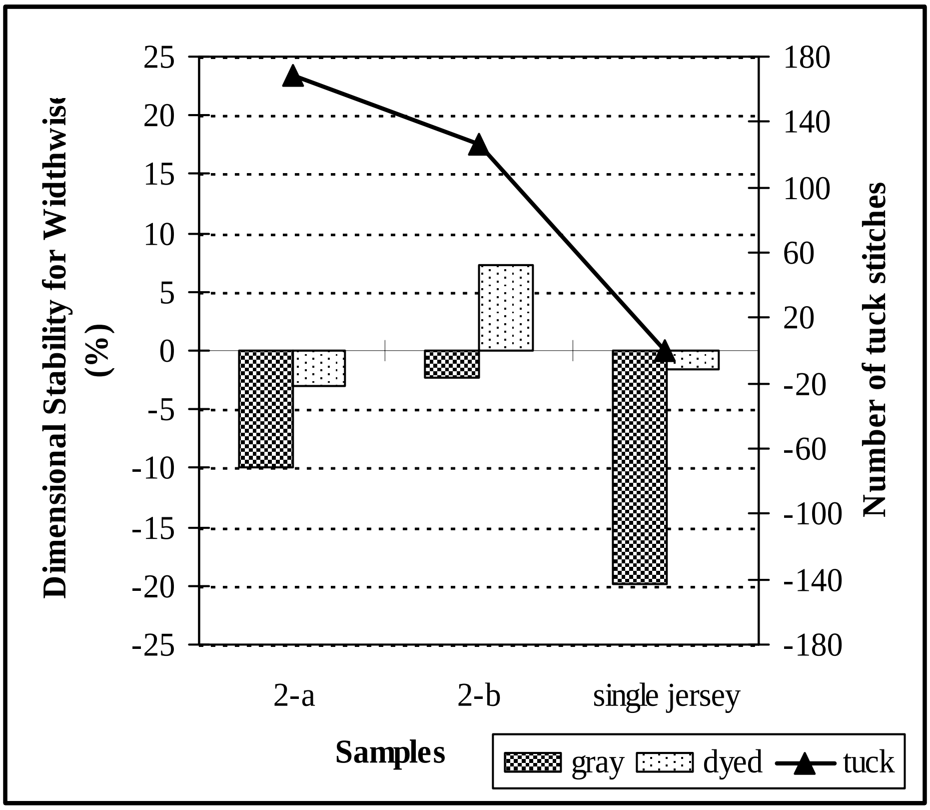


Figure 4.6 Dimensional stability of the 2nd group after 5 laundering

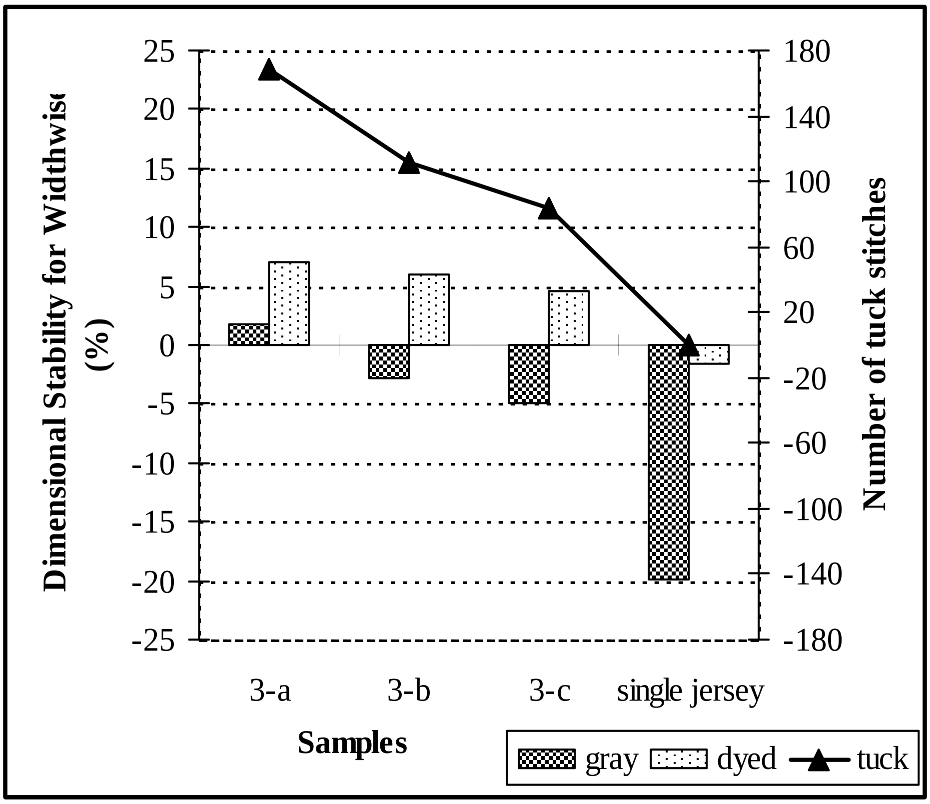


Figure 4.7 Dimensional stability of the 3rd group after 5 laundering

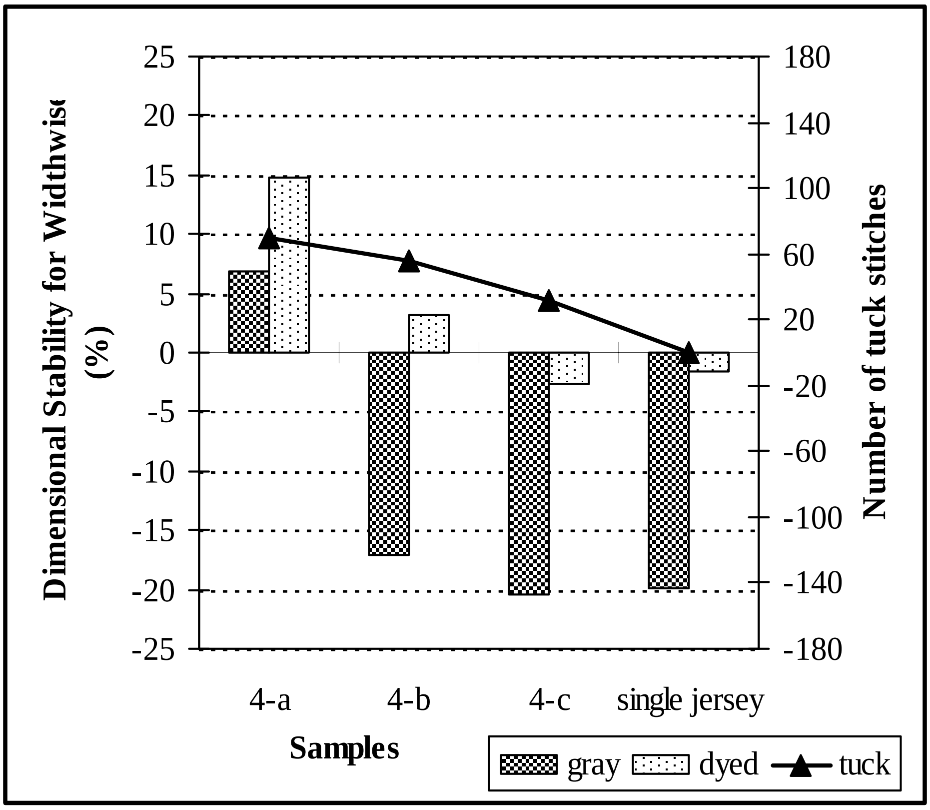


Figure 4.8 Dimensional stability of the 4th group after 5 laundering

In Figure 4.7 and Figure 4.8, it is clearly seen that as the number of tuck stitches increases the widthwise shrinkage values decrease for gray samples or the widthwise extension values increase for dyed samples, and also the dimensional change values of dyed samples with the tuck stitch are higher than the dimensional change values of gray samples with the tuck stitch.

It is observed that sample 4-a has the highest extension value in Figure 4.8 since it has the highest number of tuck stitches in the same needle. Besides, the shrinkage values of sample 4-c and single jersey are very close to each other in both gray and dyed samples because sample 4-c has single jersey courses.

4.2.3 Group Comparison for Dimensional Stability

For gray samples in Figure 4.9, it is seen that the lengthwise shrinkage values of gray samples with the tuck stitch are higher than single jersey and combinated samples 1-c and 4-c since they have higher number of tuck stitches, and also the lengthwise shrinkage values are very close out of samples 1-c, 4-c, and single jersey for other samples with the tuck stitch.

It is also observed that while the lengthwise shrinkage values increase the widthwise shrinkage values decrease. On the contrary while the lengthwise shrinkage values decrease, the widthwise shrinkage values increase. Single jersey has the lowest lengthwise shrinkage (-6.21%).

The widthwise shrinkage of single jersey and combinated samples 1-c, 4-c are almost same since samples 1-c and 4-c have single jersey courses. It is clearly seen that sample 4-a having the highest number of tuck stitches in the same needle (5 tucks) has the highest widthwise extension (6.94%) since the tuck stitch gives effect of widening to the weft knittted fabrics, and also the large loops which come after the tuck stitches in the same needle cause shrinking of courses in the lengthwise direction of fabrics as mentioned before.

The final result seen from this figure is that the 3rd group-lacoste type fabrics have the lowest dimensional change values for the widthwise direction since they are completely balanced according to the placement of tuck stitches.

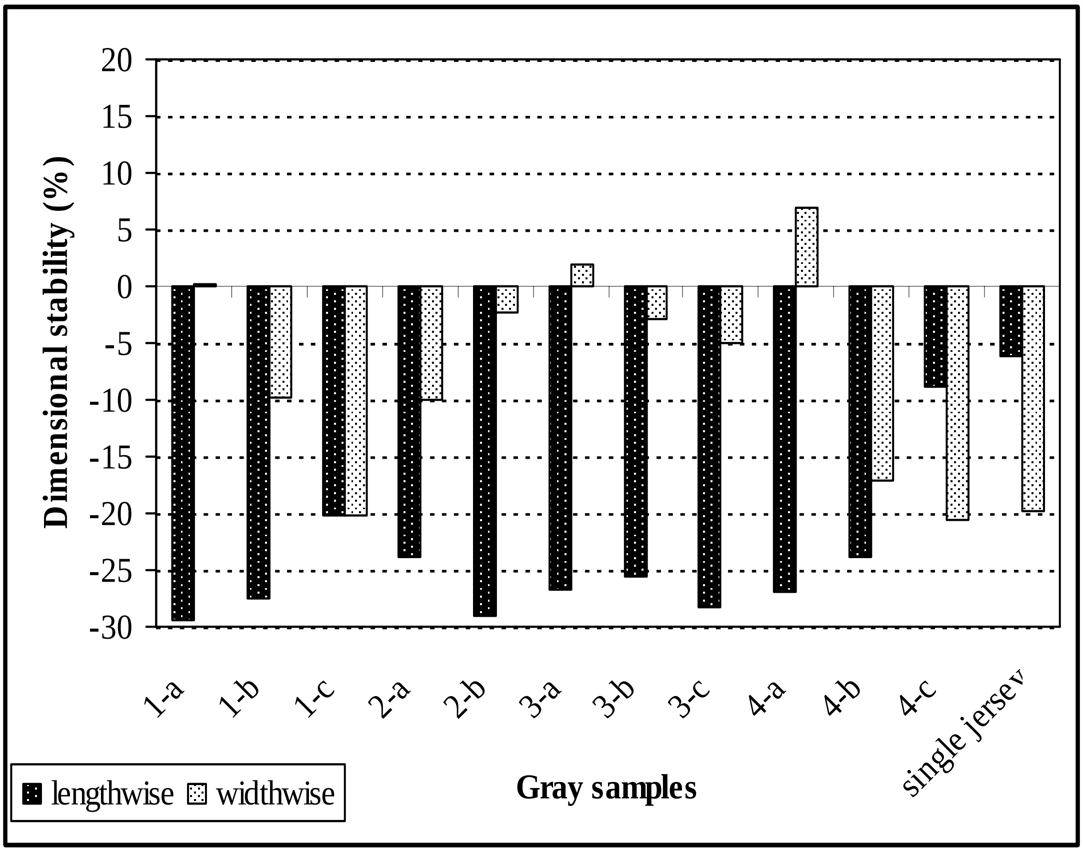


Figure 4.9 Dimensional stability of gray samples for lengthwise and widthwise

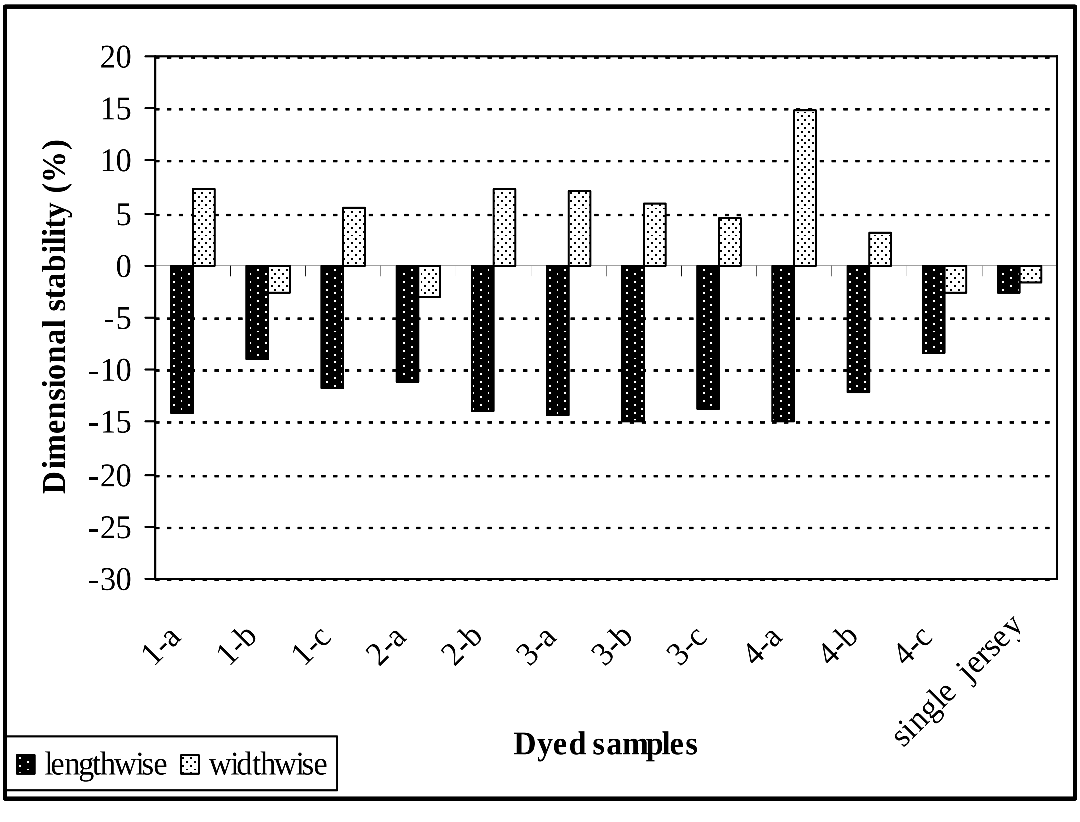


Figure 4.10 Dimensional stability of dyed samples for lengthwise and widthwise

For dyed samples in Figure 4.10, it is seen that the lengthwise shrinkage values of samples with tuck stitch are very close. Single jersey has the lowest dimensional change for lengthwise (-2.55 %), and widthwise (-1.61%). It is clearly seen that dyed samples having the more number of tuck stitches have the widthwise extension values. Otherwise, as the number of tuck stitches decreases, the extension values decrease. Sample 4-a having the highest number of tuck stitches in the same needle has the highest widthwise extension value (14.77 %). All samples of the 3rd group (lacoste type) have the widthwise extension values.

In addition to these, it is observed that the shrinkage values of dyed samples are lower than the shrinkage values of gray samples from figure because dyed fabrics are fully relaxed by disappearing of take-down tension effect as mentioned before.

4.2.4 Statistical Analysis for Dimensional Stability

According to ANOVA, effect of the number of tuck stitches on the dimensional stability was found to be significant at %1 significance level.

The correlation test results have shown that there was an important, negative and significant relationship between the number of tuck stitches and the lengthwise dimensional stability values. This means that an increase in the number of tuck stitches causes an increase in the lengthwise shrinkage values.

As for the widthwise dimensional stability, the correlation test results have shown that there was an important, positive and significant relationship between the number of tuck stitches and the widthwise dimensional stability values except dyed fabrics of the 2nd group. The positive correlation means that while the number of tuck stitches increases the widthwise shrinkage values of samples decrease, and also the widthwise extension values increase. For the 2nd group, the correlation test was performed between the samples with the tuck stitch. In this group, the negative correlation means that as the number of tuck stitches increases the shrinkage values increase or the extension values decrease in dyed samples in the widthwise direction.

The correlation coefficients and the regression equations of all groups were given in Table 4.2 and Table 4.3. Following signs are used in these tables and the next tables;

T **:** The number of tuck stitches

****** **:** Correlation is significant at 1% significance level.

***** **:** Correlation is significant at 5% significance level.

0 **:** Correlation is insignificant.

\+ **:** Positive correlation

– **:** Negative correlation

Table 4.2 Correlation and regression results for lengthwise dimensional stability

Fabric	Correlation (r) coefficient		Regression Equation	
	Gray	Dyed	Gray	Dyed
1st group	-0.973**	-0.844**	DS= -0.355 T – 6.064	DS= -0.156 T – 2.894
2nd group	-0.874**	-0.856**	DS= -0.122 T – 2.064	DS= -0.060 T– 3.295
3rd group	-0.825**	-0.853**	DS= -0.124 T – 0.362	DS= -0.074 T – 4.662
4th group	-0.929**	-0.956**	DS= -0.319 T – 3.810	DS= -0.174 T – 2.618

Table 4.3 Correlation and regression results for widthwise dimensional stability

Fabric	Correlation (r) coefficient		Regression Equation	
	Gray	Dyed	Gray	Dyed
1st group	0.904**	0.452*	DS= 0.261 T – 19.962	DS= 0.053 T + 0.423
2nd group	0.727**	-0.967**	DS= 0.077 T– 18.284	DS= -0.243 T + 37.870
3rd group	0.933**	0.827**	DS= 0.124 T – 17.955	DS= 0.053 T– 0.870
4th group	0.711**	0.765**	DS= 0.307 T – 24.766	DS= 0.209 T – 4.820

4.3 BURSTING STRENGTH

Graphics of each group were plotted separately with respect to the number of tuck stitches. Table 4.4 shows the bursting strength values of samples obtained from the tests.

Table 4.4 Bursting strength values of samples

Samples	**Single jersey**	**1-a**	**1-b**	**1-c**	**2-a**	**2-b**
Gray (kPa)	687,7	384,5	406,7	428,1	773,8	722,6
Dyed (kPa)	725,4	355,7	362,6	399,5	666,6	520,6
Samples	**3-a**	**3-b**	**3-c**	**4-a**	**4-b**	**4-c**
Gray (kPa)	680,1	652,8	689,2	433,7	555,5	578,3
Dyed (kPa)	598,8	540,4	616,4	371,9	486,1	495,5

In Figure 4.11, it is seen that as the number of tuck stitches decreases the bursting strength values increase for both gray and dyed samples. The reason of this situation is that the weft knitted fabrics having the tuck stiches are porous structures. Thus, the bursting strength of the knitted fabrics decreases when the number of pores and size of pores increases.

It is observed that the bursting strength values in all of dyed samples are lower than the bursting strength values in all of gray samples except single jersey. This result can be explained that there are waxes and oils come from yarn and knitting elements on gray fabrics. These provide that fibers which come out of yarn section stick on yarn, and so the yarn strength increases. This result can be supported by the researchers, Shahbaz [49], Ertugrul and Nuray [15]. Shahbaz [49] revealed that fabric strength largely depends upon the yarn strength. Ertugrul and Nuray [15] reported that the fabric weight, the yarn strength and the yarn elongation are the major parameters that affect the bursting strength of knitted fabrics. Finally, the decrease on the yarn strength causes the decrease on the bursting strength.

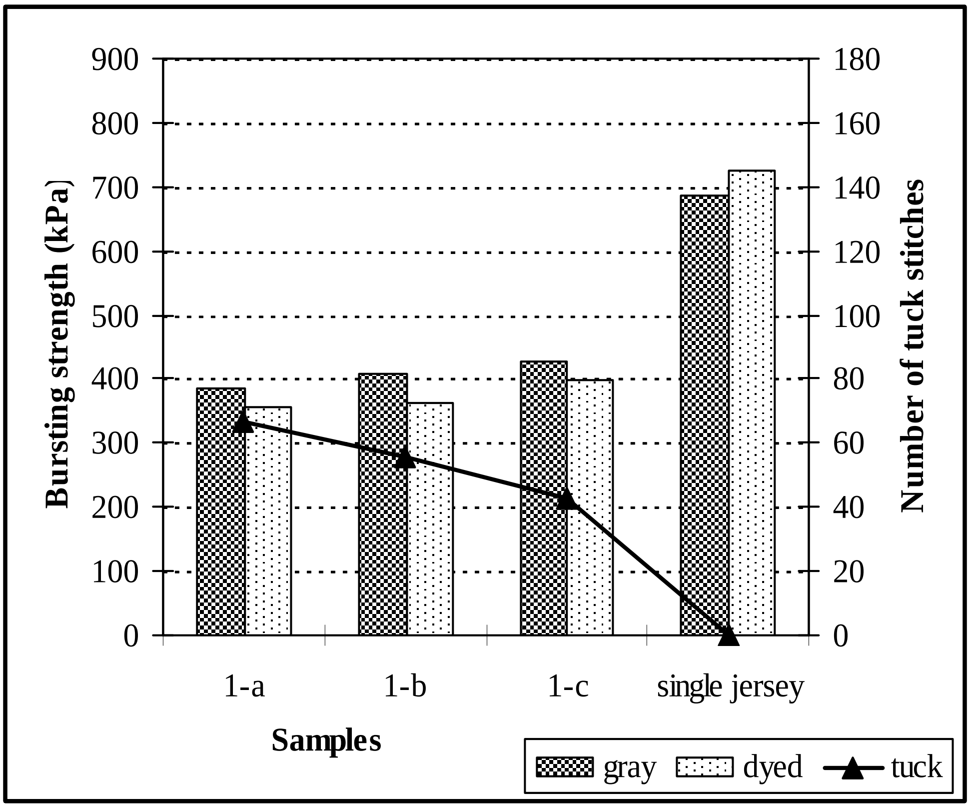


Figure 4.11 Bursting strength values of the 1st group

As for single jersey, the bursting strength of dyed sample is higher than the bursting strength of gray sample. The reason of this is that the loop density of dyed sample (310 stitch) is higher than the loop density of gray sample (262 stitch). Because, the constriction of fabric width in single jersey (-19%) is more than the constriction of fabric width in the other fabrics (-16%-+3%) after dyeing. Otherwise, increase in the loop density of samples having the tuck stitch is lower than increase in the loop density of single jersey.

As it can be seen in Figure 4.12 for gray samples; although as the number of tuck stitches decreases the bursting strength values increase in the 1st group samples, as the number of tuck stitches decreases the bursting strength values decrease in the 2nd group. Because the miss stitch effects of samples 2-a, and 2-b are appeared as explained in before. The miss stitch reduces the number and size of pores in the weft knitted fabrics. Moreover, it causes tigthness on the fabric according to single jersey. On account of this, tigthness increases, and also because of this the bursting strength values increase when the number of tuck stitches in the adjacent needles and courses increases.

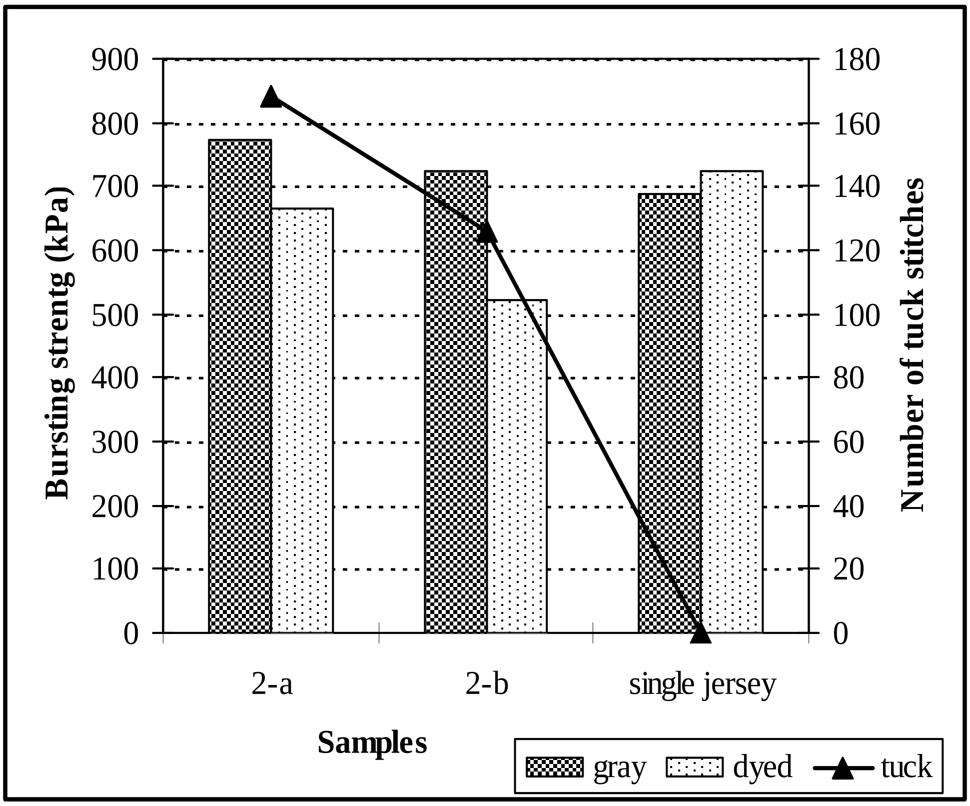


Figure 4.12 Bursting strength values of the 2nd group

In Figure 4.13, it is seen that the bursting strength values of all gray samples are very close. Thus it is noted that the number of tuck stitches does not have any effect on the bursting strength values of gray samples. According to this figure, as the number of tuck stitches decreases the bursting strength values of dyed samples increase except sample 3-a. Because the pore size of sample 3-a is smaller than the pore size of sample 3-b, the bursting strength value of sample 3-a is higher than the bursting strength value of sample 3-b. As mentioned before, the bursting strength values of dyed samples with the tuck stitch are lower than the bursting strength values of gray samples with the tuck stitch except single jersey.

In Figure 4.14, it is clearly seen that while the number of tuck stitches decreases the bursting strength values of samples increase for both gray and dyed fabrics.

Finally, it is also observed that the bursting strength values of dyed samples with the tuck stitch are lower than the bursting strength values of gray samples with the tuck stitch for all groups as become in the 1st group.

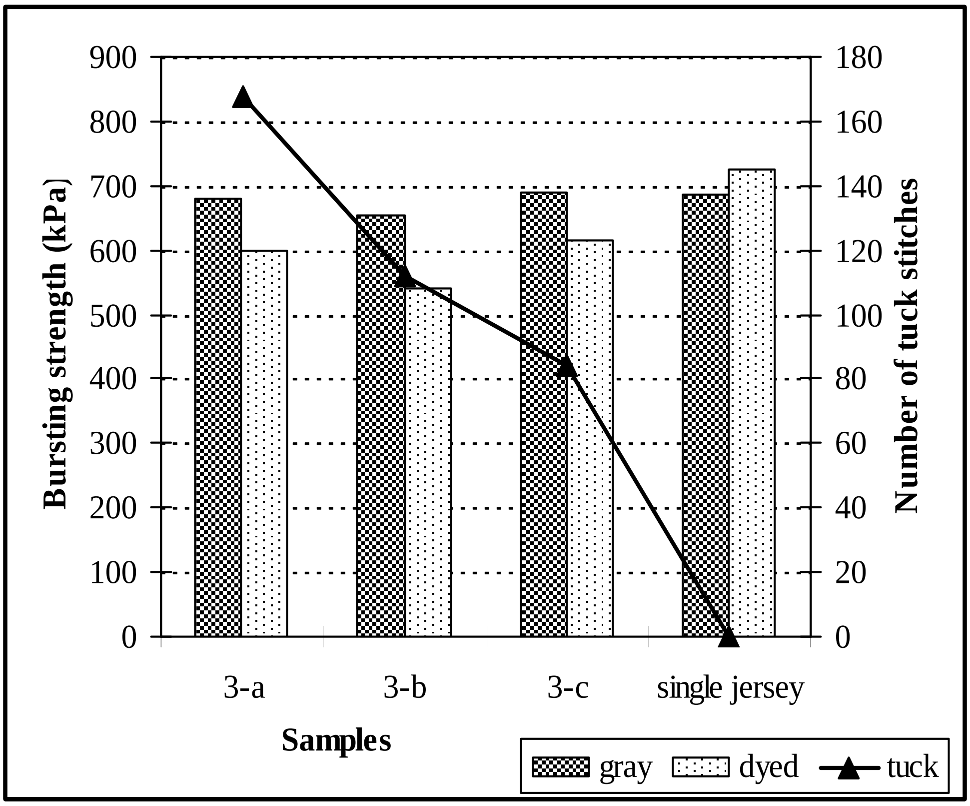


Figure 4.13 Bursting strength values of the 3rd group

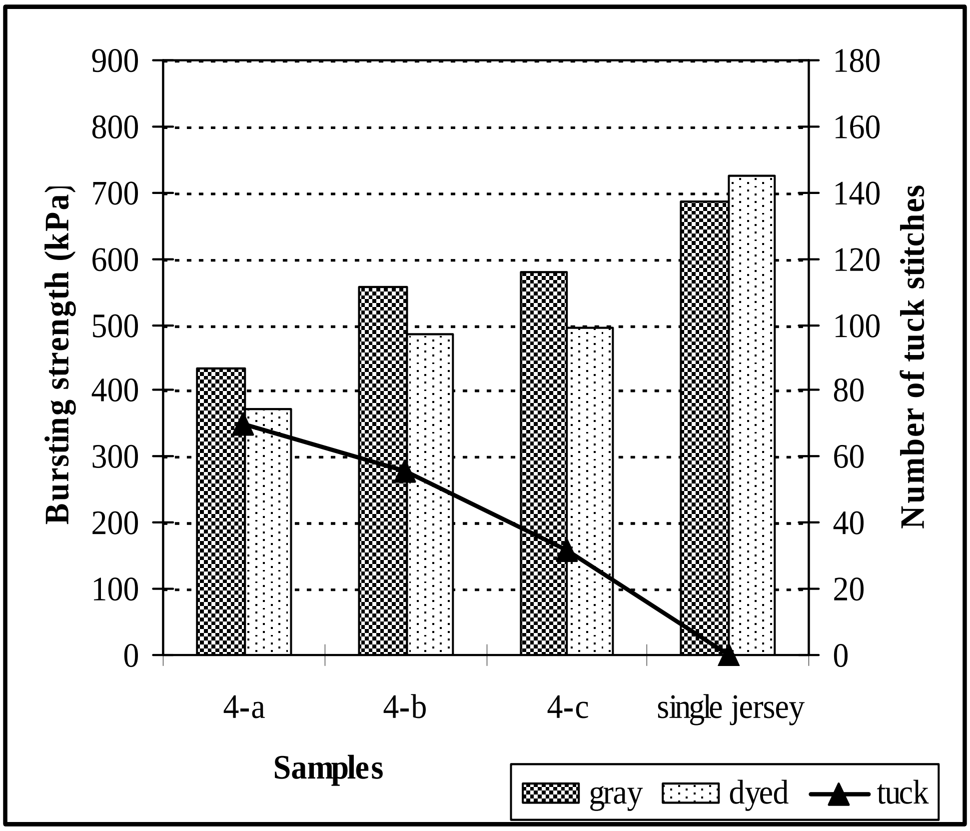


Figure 4.14 Bursting strength values of the 4th group

4.3.1 Group Comparison for Bursting Strength

According to Figure 4.15, there are important differences in the bursting strength values of samples between some groups. Especially, it is observed that the bursting strength values of 1st group samples are much lower than the bursting strength values of other groups. Because, these samples are not zigzag, and also the pores of these fabrics are larger since the tuck stitches are higher in the same needles. So it is noted that when the size of pores decreases, the bursting strength values of knitted fabrics increase.

The bursting strength values of 2nd group samples and 3rd group samples are very close and also very high. Because, the number of tuck stitches in the same needles of these groups samples are almost same, and also these samples are zigzag. The pores in these zigzag samples are smaller since the placement of tuck stitches in the needles changes.

In addition to this, the bursting strength values of 2nd group samples are higher than the bursting strength values of 3rd group samples since the miss stitch effect in the 2nd group samples reduces the pore size of samples.

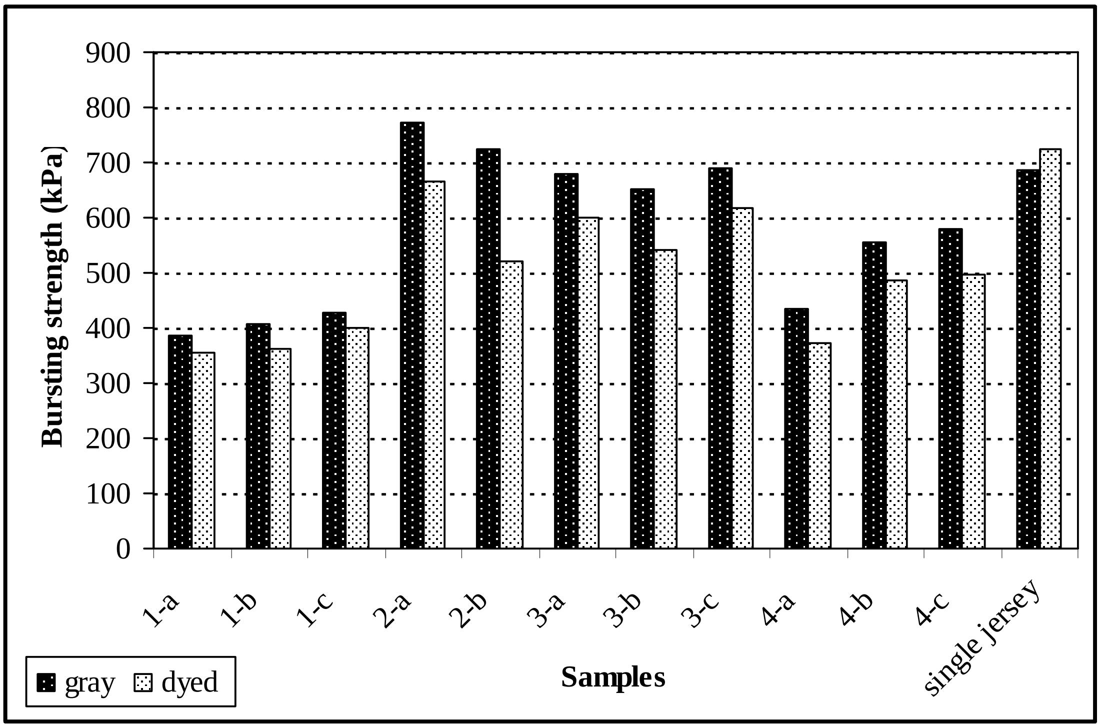


Figure 4.15 Bursting strength values of gray and dyed samples

Although the number of tuck stitches of 4th group samples and 1st group samples are close, the bursting strength values of 4th group samples are higher than the bursting strength values of 1st group samples. The reason of this is that the 4th group samples are also zigzag effect. Besides, the number of tuck stitches in the same needles of 4th group samples is higher than the number of tuck stitches in the same needles of 3rd group samples. Because of this, the bursting strength values of 4th group samples having larger pores are lower than the bursting strength values of 3rd group samples having smaller pores.

The final result is found that although the loop density of dyed samples are higher than the loop density of gray samples, the bursting strength values of dyed samples with the tuck stitch are lower than the bursting strength values of gray samples with the tuck stitch by cleaning of waxe and oil which increases yarn strength in gray fabrics. Otherwise, increase in the loop density of samples having the tuck stitch is lower than increase in the loop density of single jersey. Therefore, it can be noted that increase in the loop density does’t have very important influence on the bursting strength for fabrics having the tuck stitches as become in single jersey.

4.3.2 Statistical Analysis for Bursting Strength

ANOVA test results revealed that the number of tuck stitches has a significant effect on the bursting strength in gray and dyed samples at %1 significance level.

The correlation analysis has shown that between the number of tuck stitches and the bursting strength values of gray and dyed samples the correlation was significant and negative in the 1st group, the 3rd group and the 4th group. This means that an increase on the number of tuck stitches causes a decrease of the bursting strength values of gray and dyed samples.

On the contary, the correlation is positive in the 2nd group. In this group, as the number of tuck stitches increases the bursting strength values of gray and dyed samples increase. Besides, it is also determined that the number of tuck stitches of samples doesn’t have an important influence on the bursting strength values of gray samples in the 3rd group.

The correlation and the regression tests were performed as taken into consideration samples with the tuck stitch in dyed samples of the 2nd group since they have given more significant correlation.

The correlation coefficients and the regression equations were presented in Table 4.5.

Table 4.5 Correlation and regression results for bursting strength

Fabric	Correlation (r) coefficient		Regression Equation	
	Gray	Dyed	Gray	Dyed
1st group	-0.967**	-0.967**	BS= -4.719 T + 672.583	BS= 5.871 T + 704.468
2nd group	0.793**	0.976**	BS= 0.458 T + 683.175	BS= 3.476 T + 82.680
3rd group	0	-0.755**		BS= -0.876 T + 699.956
4th group	-0.927**	-0.943**	BS= -3.231 T + 691.430	BS= -4.614 T + 701.989

4.4 ABRASION RESISTANCE

The abrasion resistance tests were evaluated at 2500, 5000, 7500 and 10000 cycles for gray and dyed samples by viewing the mass loss of samples. Graphics were plotted as the mass loss of samples after 10000 cycles. The number of tuck stitches of samples was also shown in graphics of each group.

The experimental studies on the abrasion resistance for 2500, 5000, 7500, and 10000 cycles were given in Appendix C.

Table 4.6 shows the mass loss values of samples obtained from the tests.

Table 4.6 Mass loss values of samples after 10000 cycles

Samples	Single jersey	1-a	1-b	1-c	2-a	2-b
Gray (%)	16,98	13,48	11,51	10,33	9,88	11,12
Dyed (%)	10,55	12,56	9,74	9,58	10,56	10,31
Samples	**3-a**	**3-b**	**3-c**	**4-a**	**4-b**	**4-c**
Gray (%)	9,72	13,59	15,22	12,66	11,97	11,42
Dyed (%)	8,52	9,95	10,98	10,85	8,06	8,55

In Figure 4.16, it is clearly seen that as the number of tuck stitches decreases, the mass loss of samples decreases for both gray and dyed samples with the tuck stitch except single jersey. The abrasion resistance values of samples having the tuck stitch are higher than the abrasion resistance value of single jersey on account that they are porous.

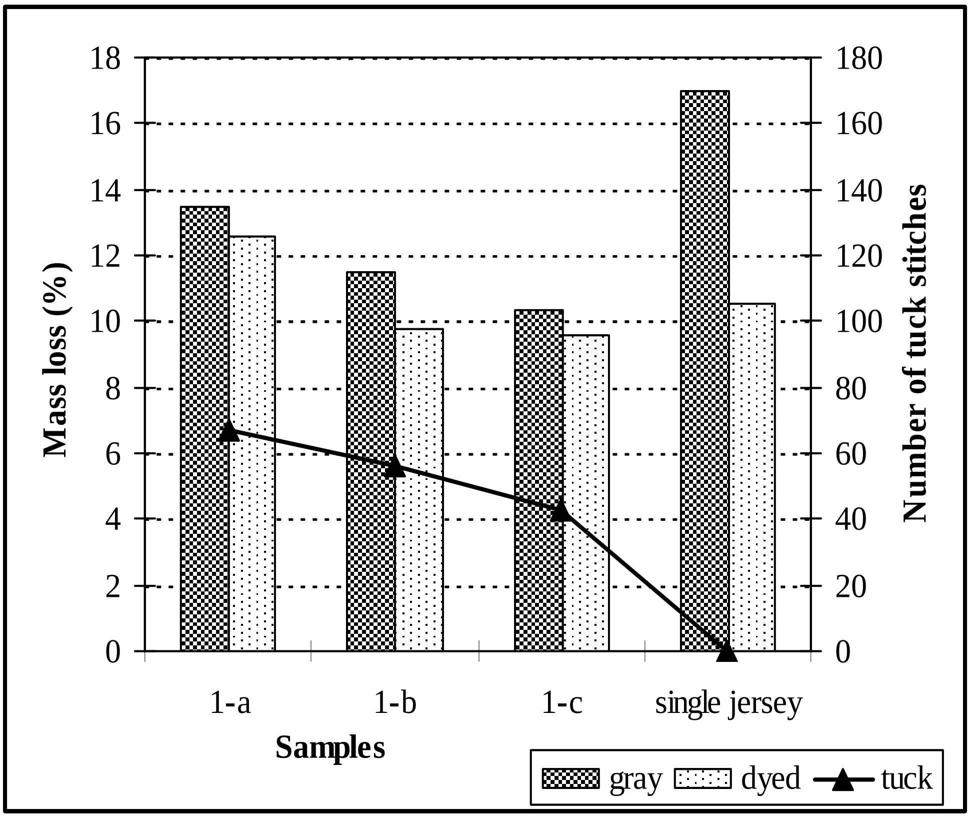


Figure 4.16 Abrasion resistance of the 1st group after 10000 cycles

Besides, it is observed that when the number of tuck stitches in the same needles increases, an important increase in cloque of fabrics, and so that decrease in the abrasion resistance values of samples with the tuck stitches. The final result found from this figure is that the abrasion resistance values of all dyed samples are higher than the abrasion resistance values of all gray samples. The reason of this is that dyed weights of samples are more than gray weights of samples because of increase on the loop density in dyed samples and regaining dyestuff.

It can be seen in Figure 4.17, as the number of tuck stitches decreases, the mass loss of samples increases for gray samples. In this group, the situation is observed to be opposite of the situation in the 1st group. This situation can be explained that the tuck stitches in the adjacent needles place on the back face of samples and the tuck stitches which give the miss stitch effect are not exposed to any abrasion. Consequently, the higher abrasion resistance values are seen in these type structures. As for dyed samples; it is seen that the abrasion resistance values of samples are very close, and also the abrasion resistance values of dyed samples are higher than the abrasion resistance values of gray samples except sample 2-a as discussed in the 1st group.

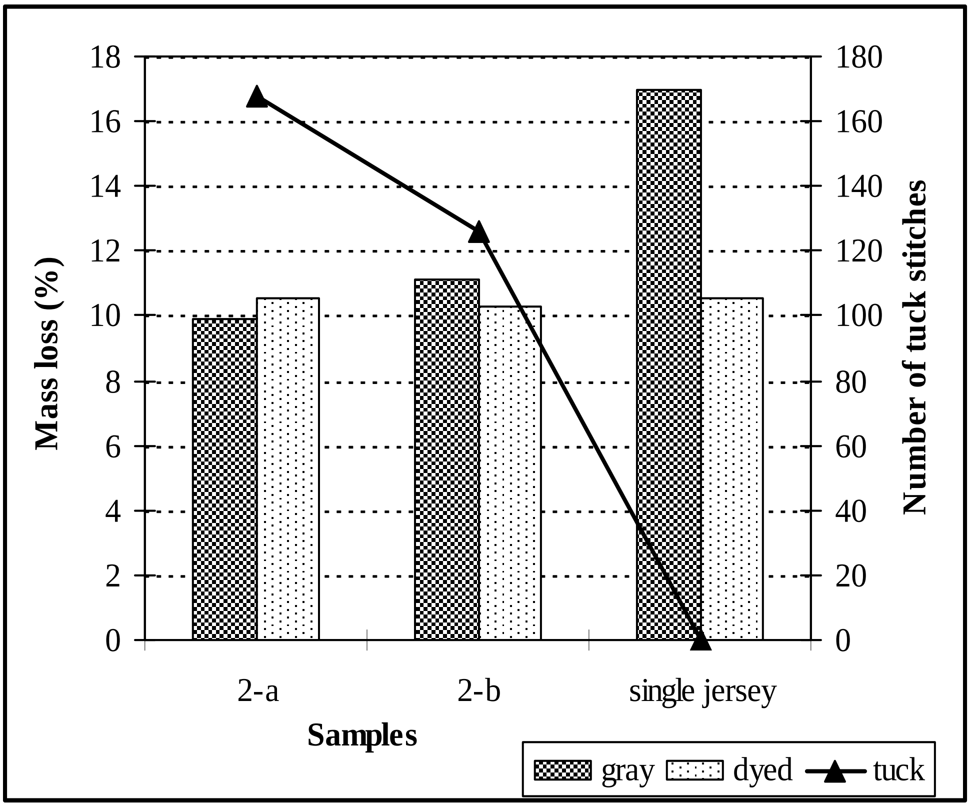


Figure 4.17 Abrasion resistance of the 2nd group after 10000 cycles

In Figure 4.18; it is seen that as the number of tuck stitches decreases, the mass loss values of samples with the tuck stitch increase for both gray and dyed samples, and also single jersey has the highest mass loss value in gray samples. As determined in samples 2-a, 2-b, there is also the same effect in sample 3-a. Because of this, sample 3-a has the highest abrasion resistance value.

Samples 3-b and 3-c have cloque structure since courses which are only composed of loops place among the other courses having the tucks and loops. Thus, the abrasion resistance values of these samples are lower than the abrasion resistance value of sample 3-a as discussed in the 1st group.

According to Figure 4.19 for gray samples, it is clearly seen that the mass loss values of samples with the tuck stitch are very close, and also as the number of tuck stitches decreases the mass loss values of samples with the tuck stitch decrease except single jersey. Sample 4-a has the cloquest structure since it has the highest tuck stitch in the same needle among the other samples with the tuck stitch. So, the abrasion resistance value of sample 4-a is the lowest one.

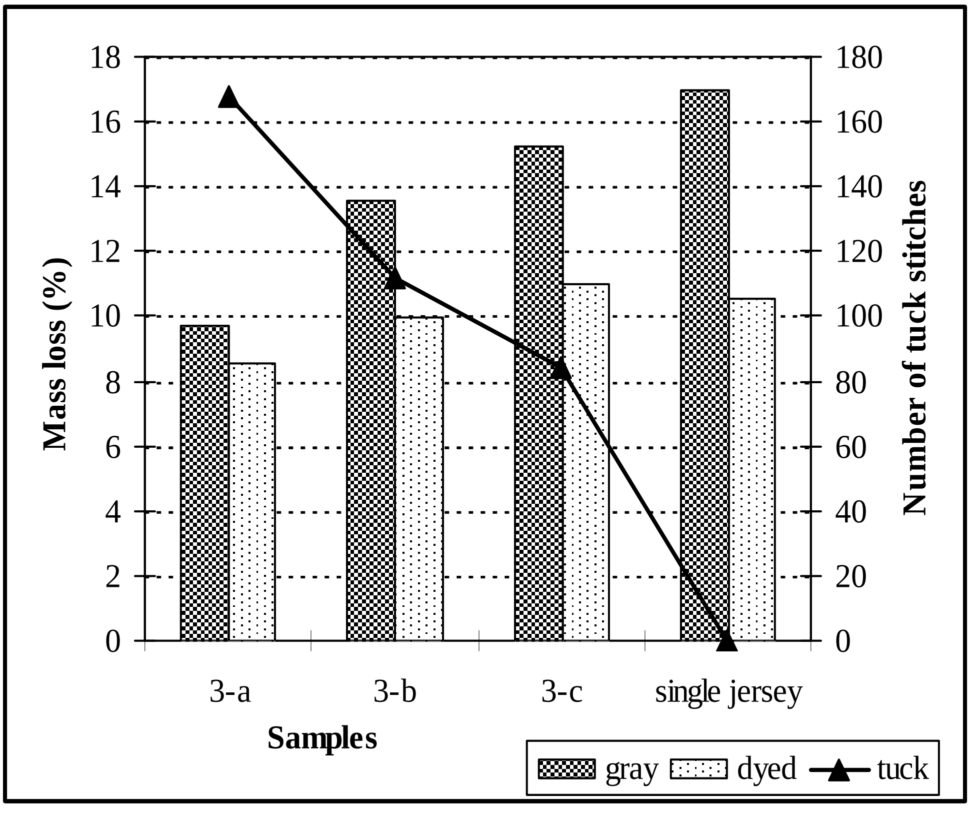


Figure 4.18 Abrasion resistance of the 3rd group after 10000 cycles

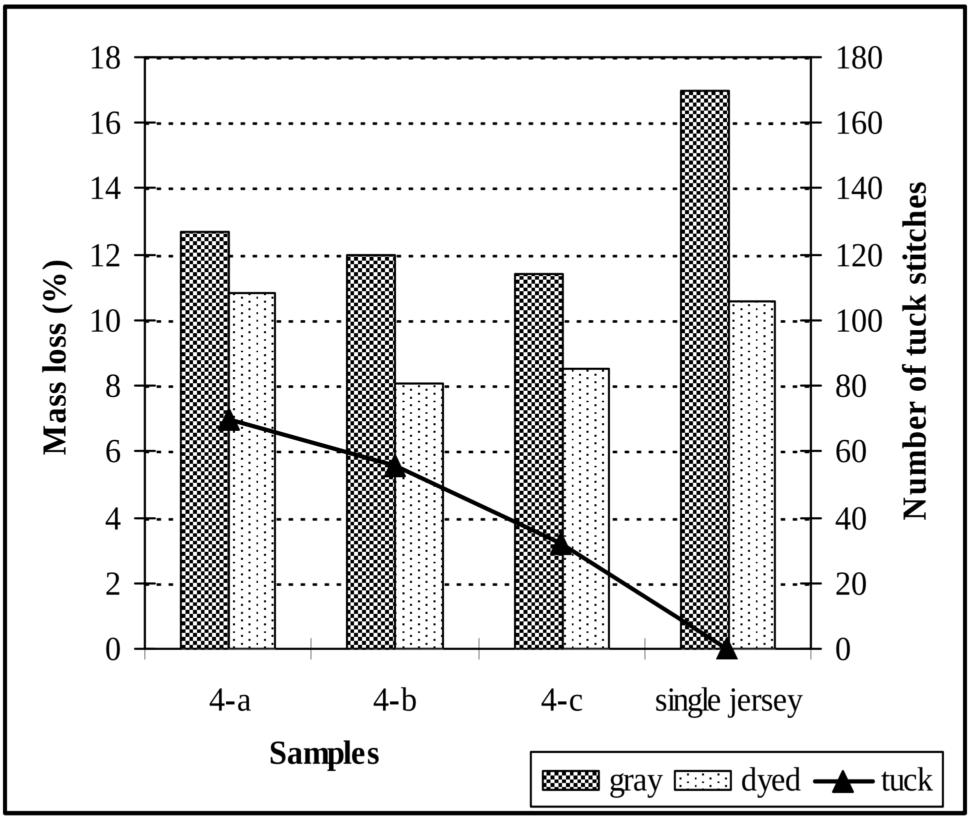


Figure 4.19 Abrasion resistance of the 4th group after 10000 cycles

In addition to these, the abrasion resistance values of dyed samples are higher than the abrasion resistance values of gray samples for all groups as mentioned before.

4.4.1 Group Comparison for Abrasion Resistance

For gray samples in Figure 4.20, it is clearly seen that single jersey having the highest mass loss value has the lowest abrasion resistance value. Because, single jersey is not porous. Abrated surface decreases in porous structures having the tuck stitches as seen in figure.

It is observed that the influence of fabric cloque is higher than the influence of number of tuck stitches and placement of tuck stitches on the abrasion resistance of gray samples with the tuck stitch. This means that unsmoothness fabrics have lower the abrasion resistance values for samples having the tuck stitches. Otherwise, samples 1-a, 3-b, 3-c, 4-a, 4-b which are cloque fabrics have lower the abrasion resistance values than the others because of decrease of the number of point which contact with abradant.

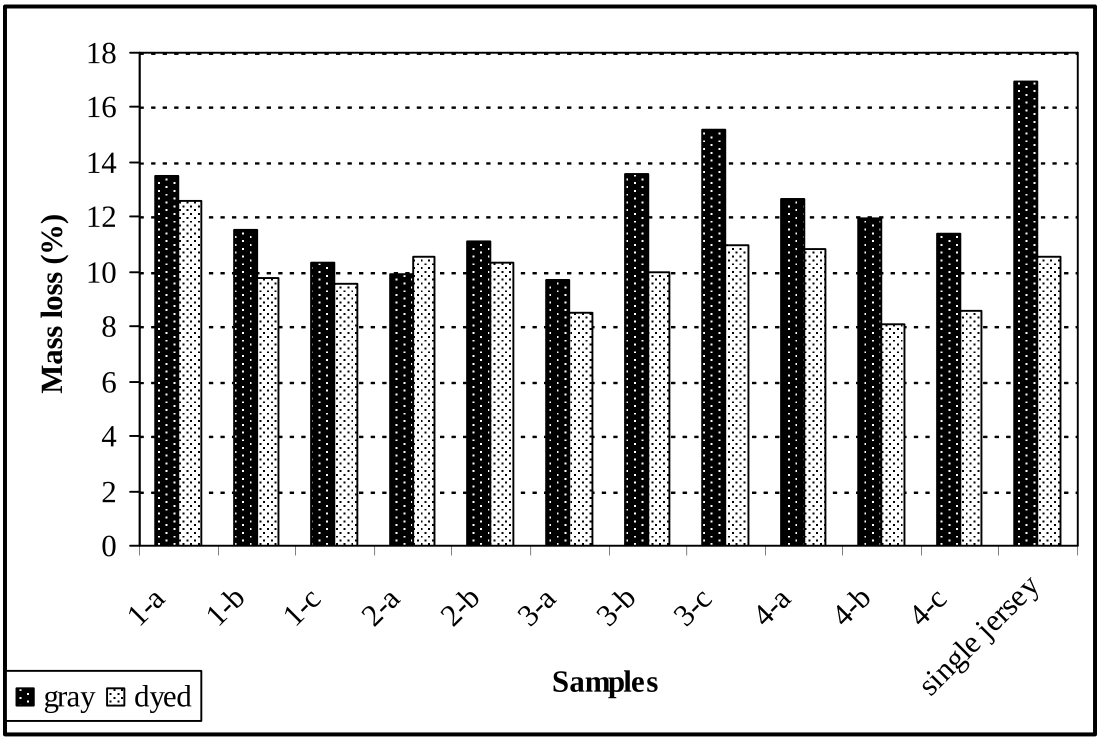


Figure 4.20 Abrasion resistance values of gray and dyed samples after 10000 cycles

Although combinated samples 1-c and 4-c are cloque, it is observed that the abrasion resistance values of samples 1-c and 4-c are much lower than expected the abrasion resistance values because of top heigth (cloque) difference between part of the tuck stitches and part of single jersey.

The abrasion resistance values of samples 2-a, 2-b and 3-a are much higher than the abrasion resistance values of the other samples, since the tuck stitches place on the back face of samples, and so that these samples resemble to double folded fabric (for example; two fleece). Because, double folded fabrics are abrated less.

For dyed samples, it is seen that the abrasion resistance values of dyed samples are higher than the abrasion resistance values of gray samples except sample 2-a as mentioned before.

4.4.2 Statistical Analysis for Abrasion Resistance

According to ANOVA, the effect of the number of tuck stitches on the abrasion resistance was found to be significant at %1 significance level.

The correlation analysis has shown that between the number of tuck stitches and the mass loss values of gray and dyed samples correlation was significant and positive in the 1st group. This means that an increase on the number of tuck stitches of samples causes a decrease on the abrasion resistance of gray and dyed samples.

In the other hand, there are negative correlations in gray samples of 2nd group, 3rd group and 4th group. In these groups, as the number of tuck stitches increases the abrasion resistance values of gray samples increase. As for dyed samples, an important correlation between the number of tuck stitches of samples and the abrasion resistance of samples was not founded in the 2nd group.

The correlation and the regression tests were performed between the samples with the tuck stitch in gray and dyed samples of the 1st group and in the dyed samples of the 3rd group, since the stronger relationship was founded between samples with the tuck stitch.

The correlation coefficients and the regression equations were given in Table 4.7.

Table 4.7 Correlation and regression results for abrasion resistance

Fabric	**Correlation (r) coefficient**		**Regression Equation**	
	Gray	**Dyed**	**Gray**	**Dyed**
1st group	0.831**	0.807**	AR= 0.130 T + 4.597	AR= 0.121 T + 3.954
2nd group	-0.970**	0	AR= -0.043 T + 16.897	
3rd group	-0.926**	-0.916**	AR= -0.042 T + 17.703	AR= -0.029 T + 13.310
4th group	-0.714**	-0.825**	AR= -0.061 T + 15.679	AR= -0.045 T + 10.386

4.5 PILLING RESISTANCE

Pilling resistance tests were evaluated by viewing the number of pills/cm^2 in samples. The studies were performed in 125, 500, 1000 and 2000 cycles. Graphics were plotted by considering the number of pills/cm^2 in samples after 2000 cycles.

The experimental studies on the pilling resistance for 125, 500, 1000, and 2000 cycles were given in Appendix D.

Table 4.8 shows the number of pills/cm^2 in samples obtained after 2000 cycles.

Table 4.8 Pill numbers of samples at 2000 cycles

Samples	**Single jersey**	**1-a**	**1-b**	**1-c**	**2-a**	**2-b**
Gray	13,1	10,2	11,3	12,2	10,4	10,4
Dyed	14,1	11,1	12,2	12,8	11,8	12,3
Samples	**3-a**	**3-b**	**3-c**	**4-a**	**4-b**	**4-c**
Gray	11,2	7,1	8	10,7	10,8	11,6
Dyed	13,3	8,6	9,4	11,5	11,3	12,2

In Figure 4.21, it is clearly seen that as the number of tuck stitches decreases, the number of pills/cm^2 increases, and so the pilling resistance values of samples decrease for both gray and dyed samples. Because, the weft knitted fabrics having the tuck stitch are porous, and the pores reduce pilling. Besides, it is observed that the pilling resistance values of dyed samples are lower than the pilling resistance values of gray samples. The first reason of this situation is that waxe and oil on fabric is removed by finishing processes, and so that easier pill formation because of decrease in adhesiveness of fibers in yarn. The second reason is that the pore size of samples decreases since the loop density of dyed samples increases according to the loop density of gray samples. Besides, single jersey has the lowest pilling resistance since it is not porous.

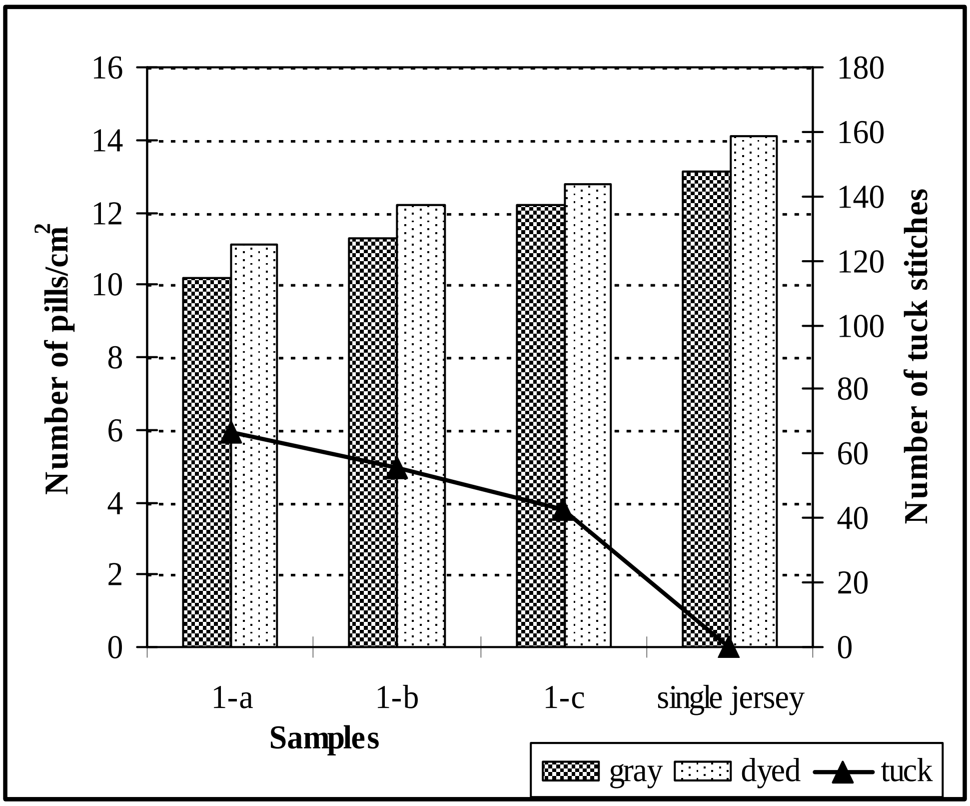


Figure 4.21 Pilling resistance of the1st group after 2000 cycles

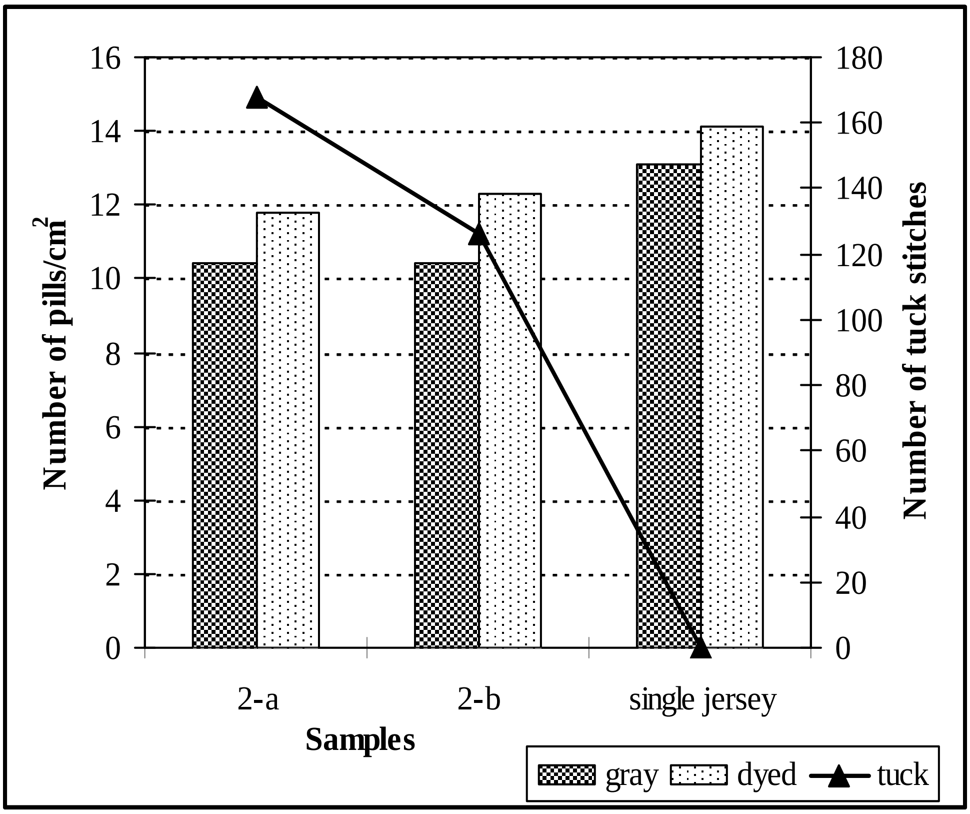


Figure 4.22 Pilling resistance of the 2nd group after 2000 cycles

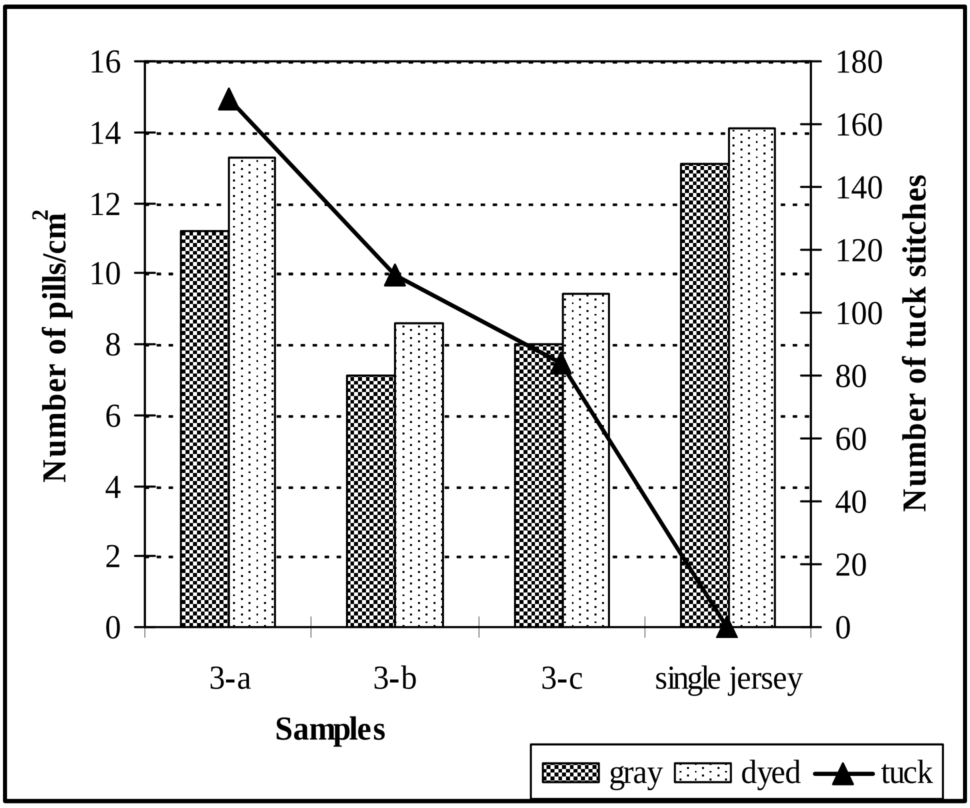


Figure 4.23 Pilling resistance of the 3rd group after 2000 cycles

As it can be seen in Figure 4.22, the number of pills/cm^2 in samples with the tuck stitch are almost the same and lower than the number of pills/cm^2 in single jersey for both gray and dyed samples since the tuck stitches place on the back face of samples and also these samples have very similar surface.

According to Figure 4.23, sample 3-b has the highest pilling resistance value since its pore size is larger than pore size of the other samples. Although the number of tuck stitches of sample 3-a are higher than the number of tuck stitches of samples 3-b and 3-c, the pilling resistance of sample 3-a is lower than the pilling resistance of samples 3-b and 3-c since the tuck stitches place on the back face in sample 3-a and as a result of this, pore size of sample 3-a decreases very much.

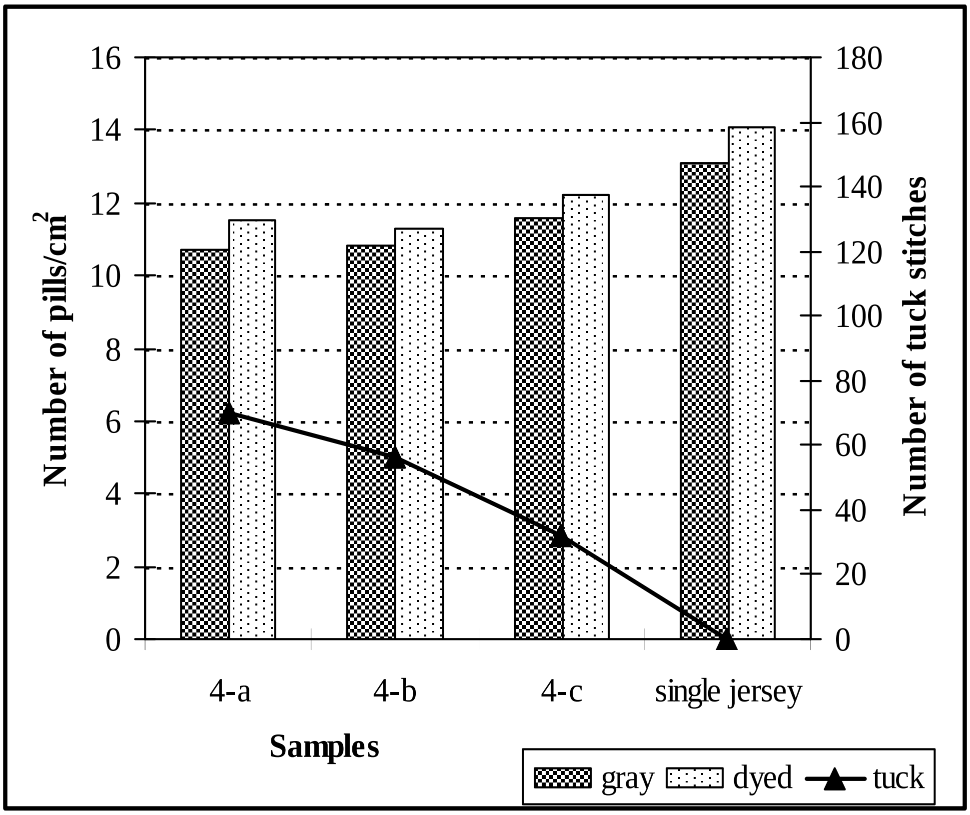


Figure 4.24 Pilling resistance of the 4th group after 2000 cycles

In Figure 4.24, as become in the other groups as the number of tuck stitches decreases, the number of pills/cm^2 increases for both gray and dyed samples because of porous structure. The final result founded from this figure is that the pilling resistance values of samples 4-a, 4-b are very close because of having very similar surface.

4.5.1 Group Comparison for Pilling Resistance

Porous structures reduce the pilling by decreasing of contact surface between fabric surface and rubbed surface. This situation is clearly seen from Figure 4.25. Fabrics having tuck stitch are porous and the pilling resistance of these samples are higher than the pilling resistance of single jersey.

It is also observed that samples 3-b and 3-c have the highest pilling resistance. Because, pattern size of these fabrics is smaller than the others, and also these are cloque fabrics. Consequently, the number of pores which forms heigth difference in the fabric is higher.

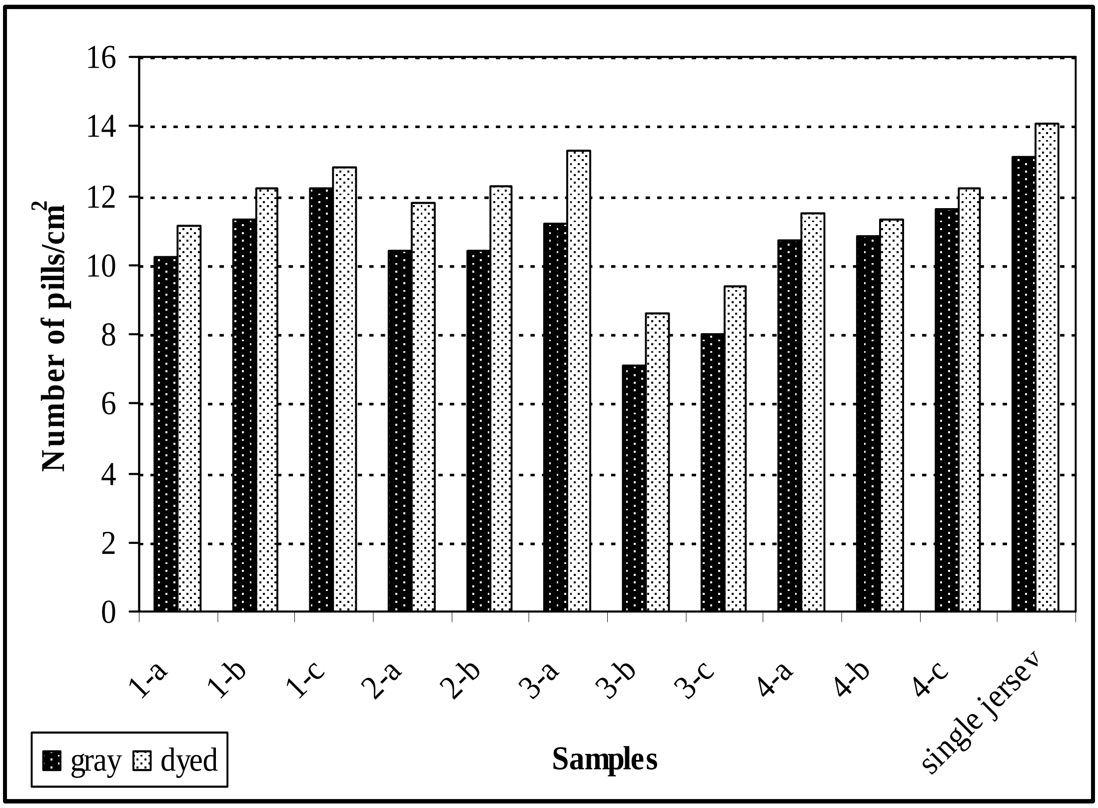


Figure 4.25 Pilling resistance values of gray and dyed samples after 2000 cycles

Although, samples 1-a, 1-c, 4-a, 4-b and 4-c are clouqe fabrics, they have lower pilling resistance than samples 3-b and 3-c. Because, the number of pores is lower by change in pattern size.

The pilling resistances of the other samples are lower since they have similarly smoothness surface as become in single jersey.

The final result found from this figure, the pilling resistance values of dyed samples are lower than the pilling resistance values of gray samples. The reasons of this are; decrease of pore size of dyed samples by shrinking, and also decrease in adhesiveness of fibers in yarn by finishing.

4.5.2 Statistical Analysis for Pilling Resistance

ANOVA test results have revealed that the number of tuck stitches had a significant effect on the pilling resistance in all samples at %1 significance level.

Based on the correlation analysis test results, the correlations between the number of tuck stitches of samples and the pilling resistance of samples are significant and negative for all groups. So that, as the number of tuck stitches of samples increases the number of pills/cm^2 decreases. The correlation coefficients and the regression equations were given in Table 4.9.

Table 4.9 Correlation and regression results for pilling resistance

Fabric	**Correlation (r) coefficient**		**Regression Equation**	
	Gray	**Dyed**	**Gray**	**Dyed**
1st group	-0.623**	-0.582**	PR= -0.039 T + 13.340	PR= -0.052 T + 14.866
2nd group	-0.661**	-0.595**	PR= -0.017 T + 13.009	PR= -0.018 T + 14.735
3rd group	-0.888**	-0.838**	PR= -0.055 T + 13.017	PR= -0.057 T + 14.662
4th group	-0.483**	-0.565**	PR= -0.034 T + 12.970	PR= -0.048 T + 14.377

4.6 FABRIC THICKNESS

Table 4.10 shows the fabric thickness values of samples as mm.

Table 4.10 Fabric thickness values of samples

Samples	**Single jersey**	**1-a**	**1-b**	**1-c**	**2-a**	**2-b**
Gray (mm)	0,441	0,559	0,542	0,517	0,587	0,599
Dyed (mm)	0,444	0,516	0,512	0,492	0,65	0,608
Samples	**3-a**	**3-b**	**3-c**	**4-a**	**4-b**	**4-c**
Gray (mm)	0,617	0,685	0,53	0,544	0,534	0,496
Dyed (mm)	0,629	0,636	0,559	0,555	0,535	0,491

According to Figure 4.26, Figure 4.27, Figure 4.28 and Figure 4.29, the thickness values of samples having the tuck stitch are close and higher than the thickness value of single jersey for both gray and dyed samples since the tuck stitch increases the fabric thickness as determined by researchers. It is also seen that as the number of tuck stitches increases, the thickness values of samples increase for all groups.

Besides, it is determined that the thickness values of dyed samples are affected by the thickness values of gray samples and the finished fabrics width which are adjusted according to the fabric width after dyeing and drying. In other words, the finished fabrics are opened more 4-6 % than the fabric width after drying. If the finished fabrics are opened very much, the loop density in unit area decreases, and so the fabric thickness also decreases. On the contrary, if the finished fabrics are opened less, the loop density in unit area increases, and so that the fabric thickness increases. Because of this reason, the finished fabric thickness may be more or less than gray fabric thickness.

In Figure 4.28, it is observed that the thickness value of sample 3-a is lower than the thickness value of sample 3-b since sample 3-b is more cloque than sample 3-a.

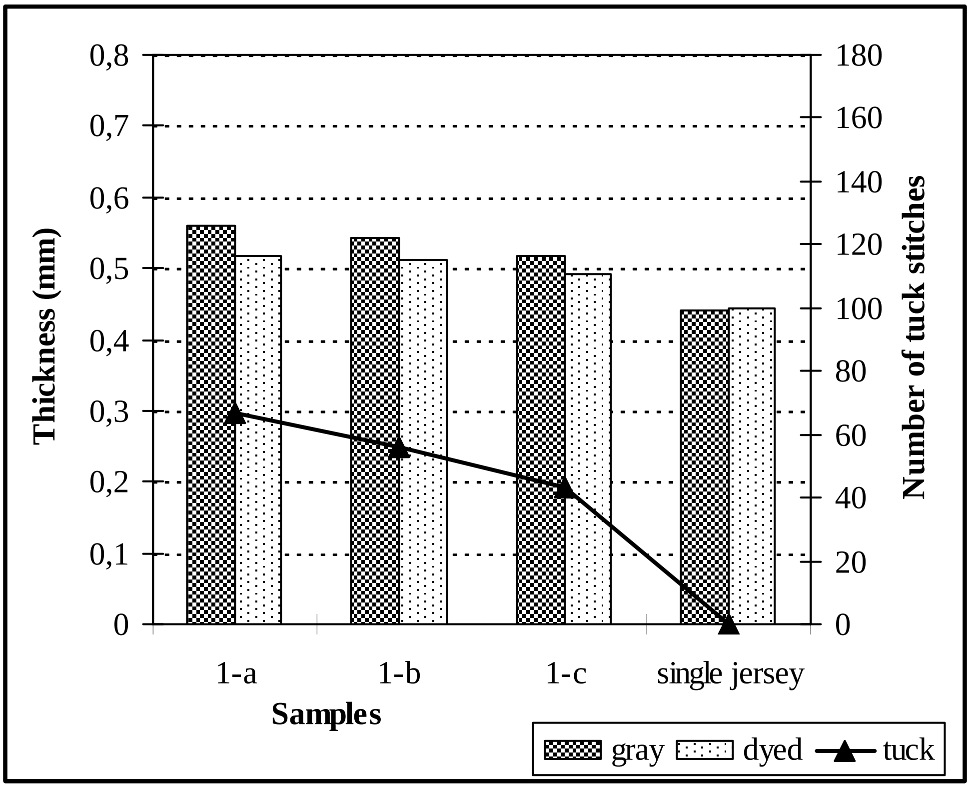


Figure 4.26 Fabric thickness values of the 1st group samples

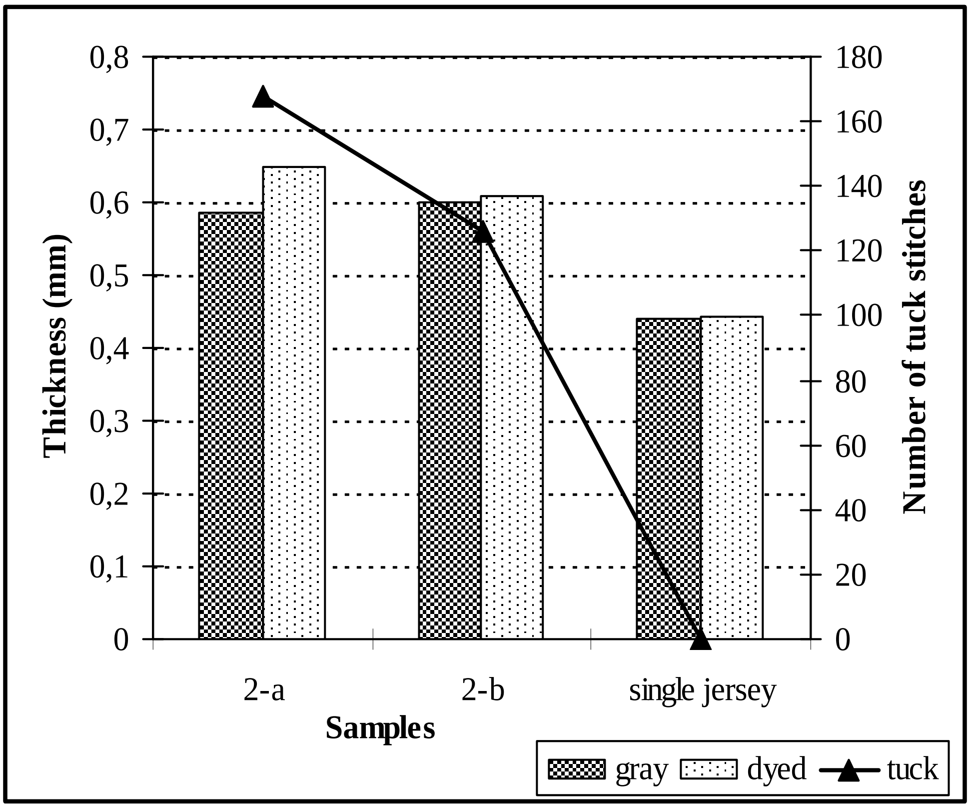


Figure 4.27 Fabric thickness values of the 2nd group samples

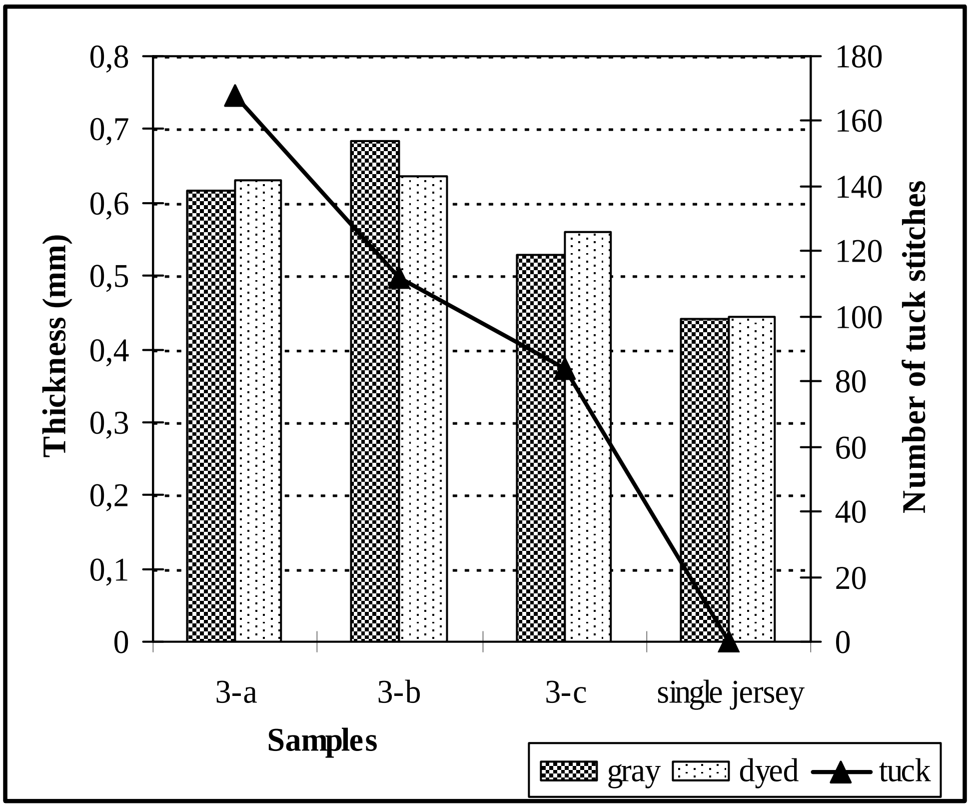


Figure 4.28 Fabric thickness values of the 3rd group samples.

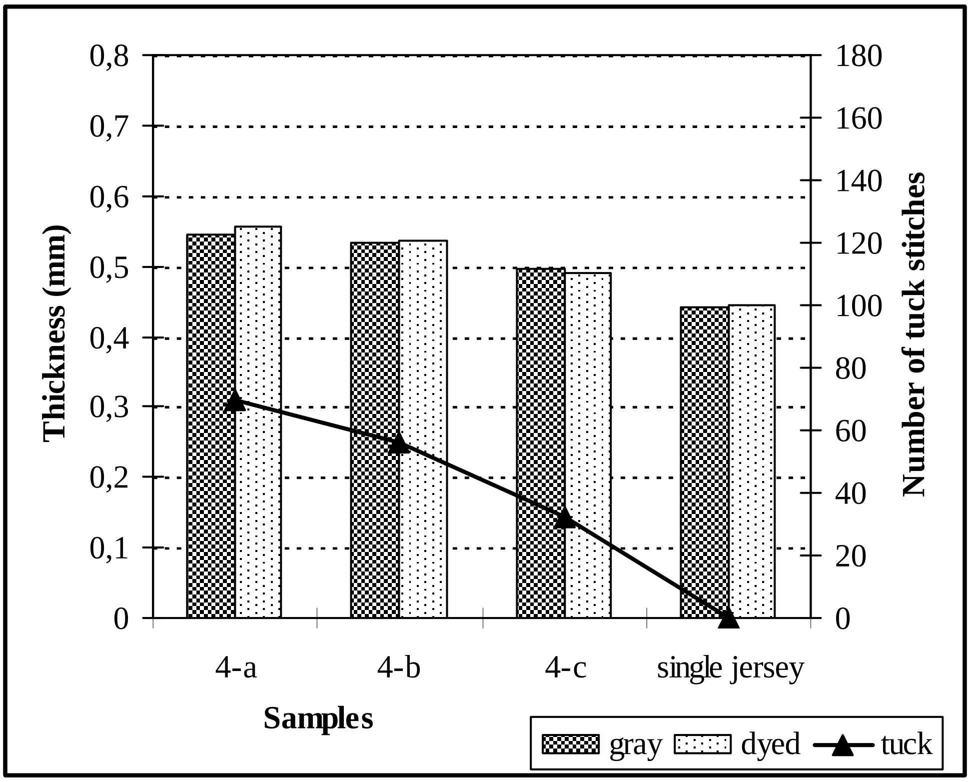


Figure 4.29 Fabric thickness values of the 4th group samples

4.6.1 Group Comparison for Fabric Thickness

In Figure 4.30, it is clearly seen that the thickness values of samples 2-a, 2-b, 3-a, and 3-b which have higher the number of tuck stitches (100+…) than the other samples are higher than the thickness values of the other samples.

At the same time, it is observed that single jersey has the lowest thickness value and also thickness values of the other samples are close except samples 2-a, 2-b, 3-a, and 3-b for both gray and dyed samples.

In the other hand, the thickness values of gray samples and the finished fabric width values have an important influence on the thickness values of dyed samples based on the loop density in unit area. In addition to this, gray thickness values and dyed thickness values are close in samples.

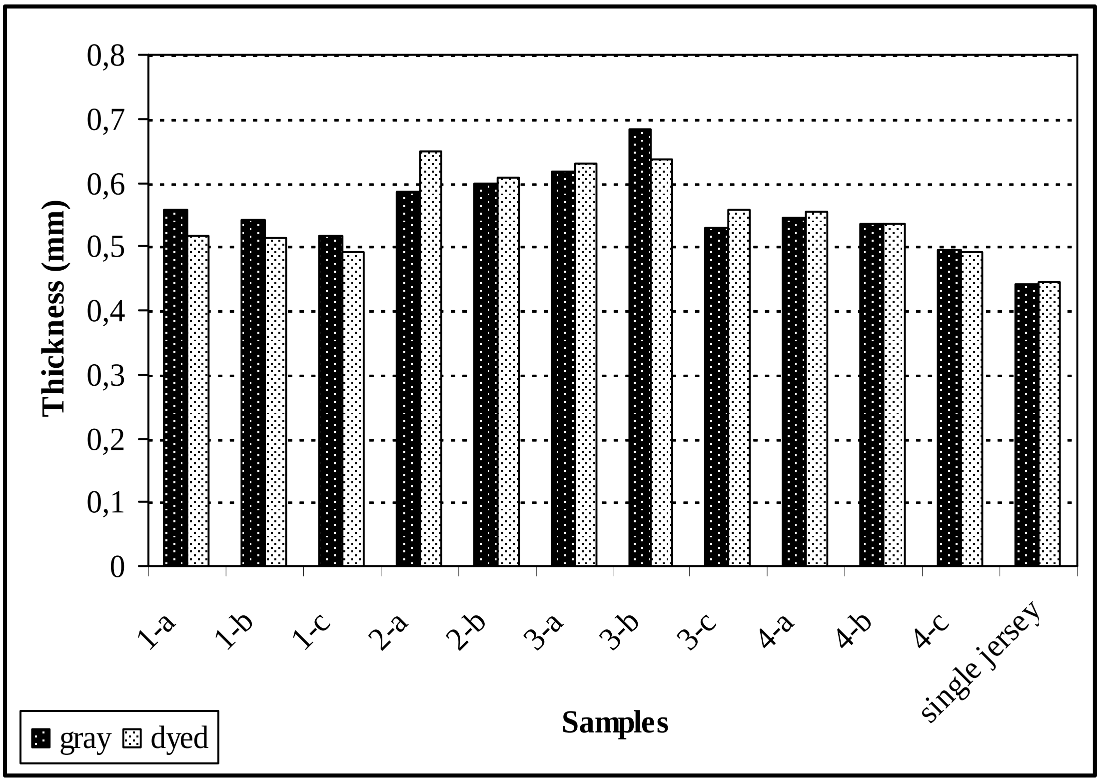


Figure 4.30 Fabric thickness values of gray and dyed samples

4.6.2 Statistical Analysis for Fabric Thickness

Table 4.11 Correlation and regression results for fabric thickness

Fabric	Correlation (r) coefficient		Regression Equation	
	Gray	Dyed	Gray	Dyed
1st group	0.733**	0.626**	FT= 0.002 T + 0.441	FT= 0.001 T + 0.445
2nd group	0.934**	0.979**	FT= 0.001 T+ 0.448	FT= 0.001 T + 0.445
3rd group	0.803**	0.912**	FT= 0.001 T + 0.456	FT= 0.001 T + 0.459
4th group	0.805**	0.736**	FT= 0.002 T + 0.444	FT= 0.002 T + 0.443

The effect of the number of tuck stitches on the fabric thickness is a significant at %1 significance level according to ANOVA.

The correlation test results showed that there was an important, positive and significant relationship between the number of tuck stitches and the fabric thickness in all fabrics. This means that as the number of tuck stitches increases the fabric thickness increases in all of samples (Table 4.11).

4.7 SPIRALITY

Graphics of each group were plotted by getting average of the spirality values and the number of tuck stitches of samples. Table 4.12 shows the spirality values of samples.

Table 4.12 Spirality values of samples

Samples	**Single jersey**	**1-a**	**1-b**	**1-c**	**2-a**	**2-b**
Gray (degree)	5,45	1,3	1,45	2,1	1,8	1,9
Dyed (degree)	3,9	0,85	1,1	2	0,9	0,6
Samples	**3-a**	**3-b**	**3-c**	**4-a**	**4-b**	**4-c**
Gray (degree)	0,75	0,75	1,25	2,75	2,35	3,8
Dyed (degree)	0,2	0,1	0,25	0,95	0,5	3,25

In the following figures, it is clearly seen that the spirality values of samples having the tuck stitches are lower than the spirality value of single jersey for both gray and dyed samples. Moreover, it is observed that as the number of tuck stitches decreases the spirality values of samples increase since the rotation tendency of tuck wales are less than the rotation tendency of loop wales. Because, internal tension of yarn in the tucks stitch is less according to internal tension of yarn in the loop.

In addition to these, it is observed that the spirality values of dyed samples are lower than the spirality values of gray samples, since dyed fabrics are fully relaxed fabrics, and also internal tension of yarn decreases after relaxation. Thus, the rotation tendency of wales decreases, and the spirality is seen less in dyed fabrics.

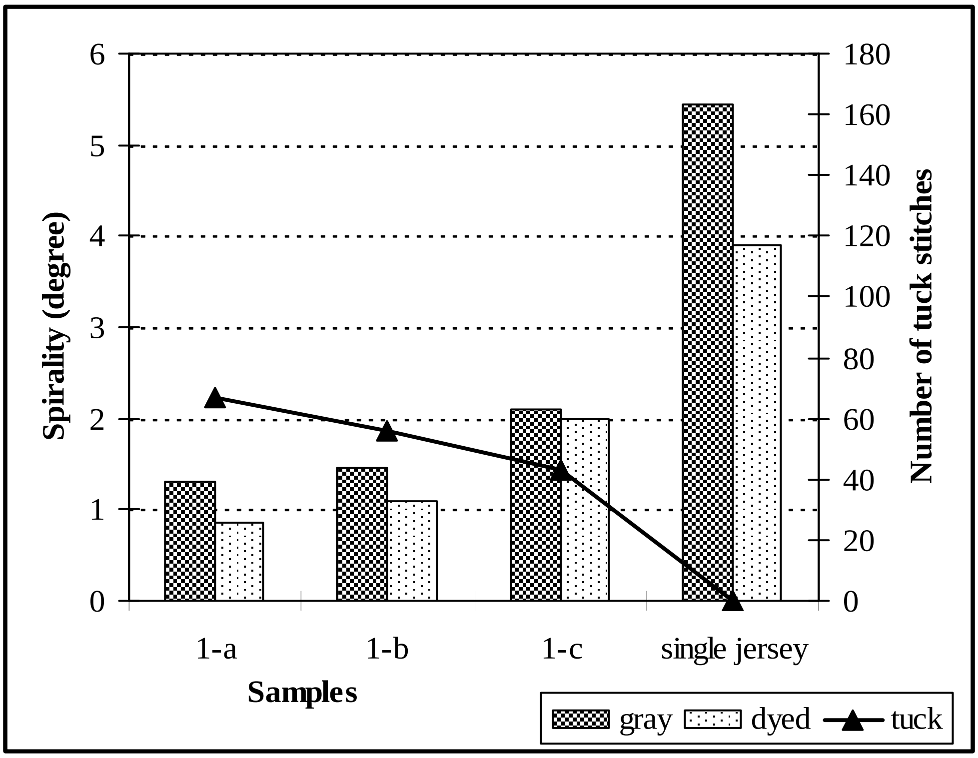


Figure 4.31 Spirality values of the 1st group samples

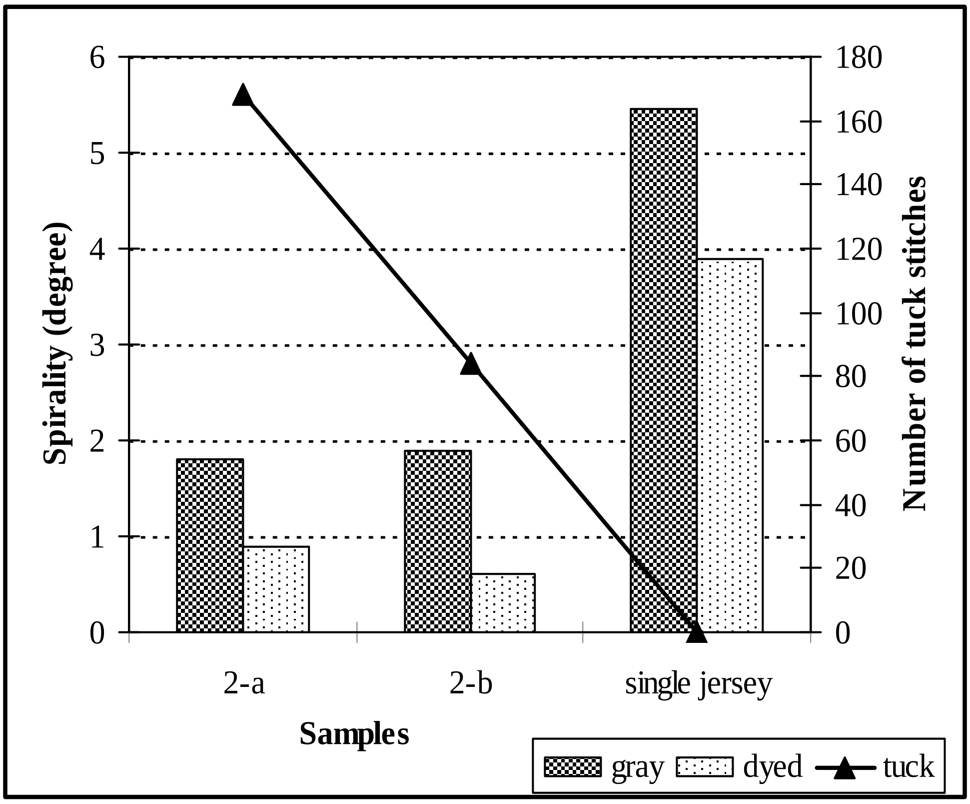


Figure 4.32 Spirality values of the 2nd group samples

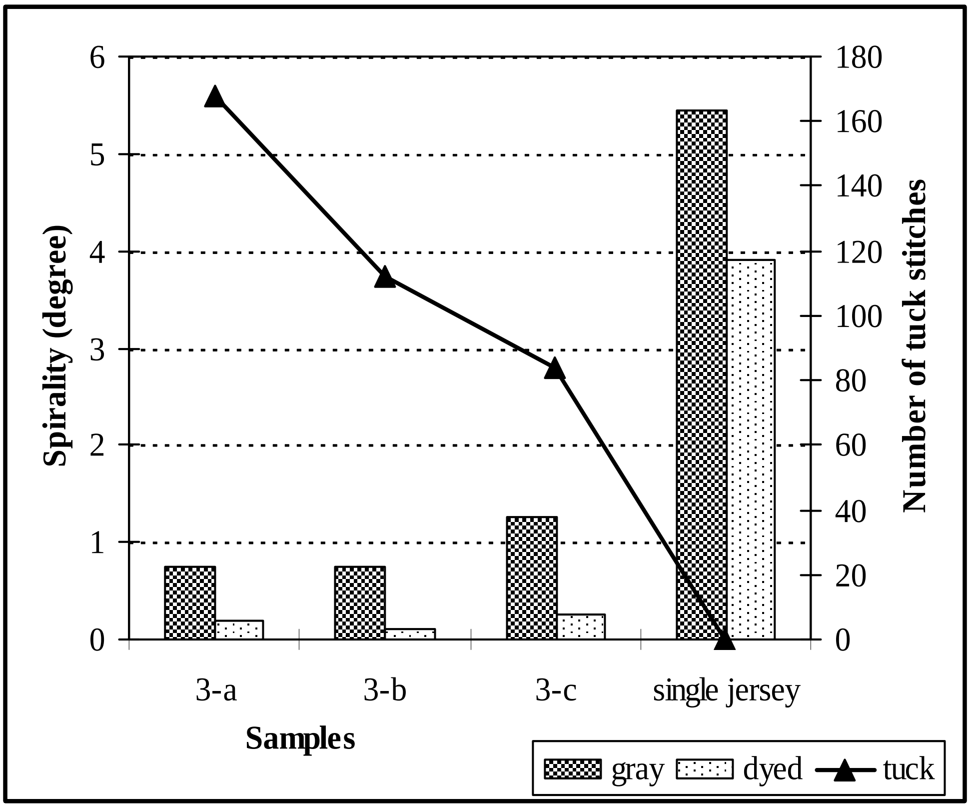


Figure 4.33 Spirality values of the 3rd group samples

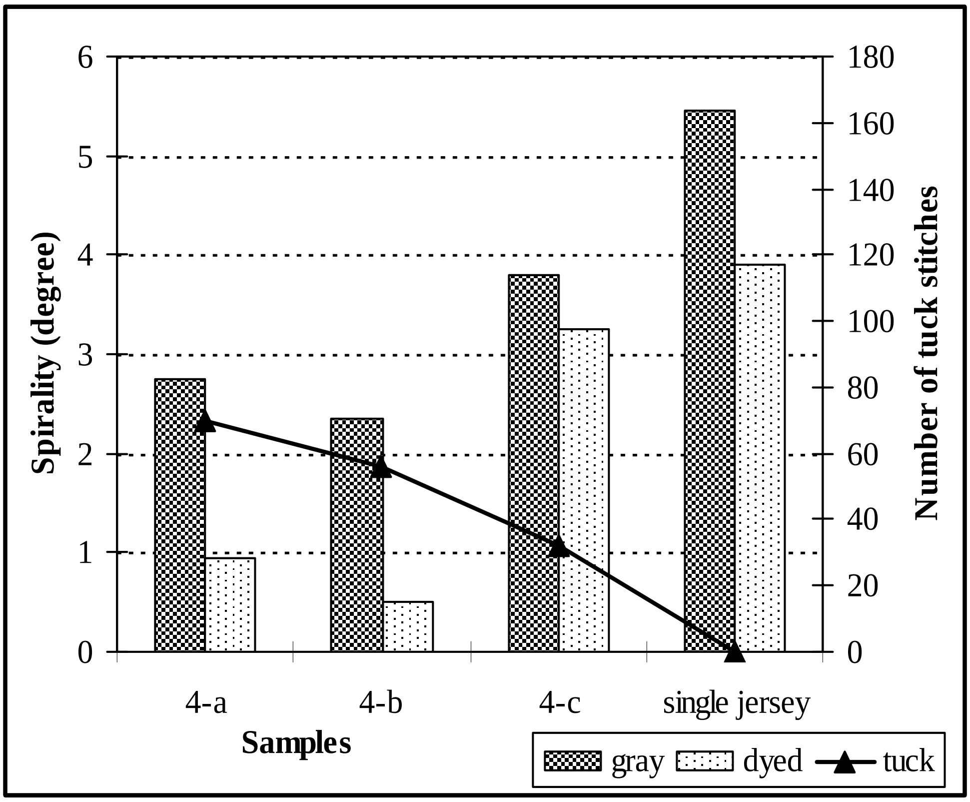


Figure 4.34 Spirality values of the 4th group samples

4.7.1 Group Comparison for Spirality

According to Figure 4.35, single jersey has the highest spirality value. Sample 3-a and sample 3-b have the lowest spirality values. Because, the wales pattern repeating is in the two needles for only the 3rd group samples, on the contrary, the wales pattern repeating is in the four needles for the other samples. In other words, there is the tuck stitch in the one needle of two adjacent needles, and this tuck stitch prevents the spirality of loop in other needle. So, the spirality reduces.

Besides, it is observed that the spirality values of the other samples are close to each other except the 4th group samples. This can be explained that the course pattern repeating of these samples are higher than the course pattern repeating of the other samples. Thus, the tuck stitch easily balances the spirality of one wale or one course, but it is forced to balance the spirality of wales or courses which are more than one.

Although the pattern and the pattern repeating of the 2nd group samples are similar to pattern and pattern repeating of the 3rd group samples, the spirality values of the 2nd group samples are higher than the spirality values of the 3rd group samples since the tuck stitch gives the miss stitch effect in these samples.

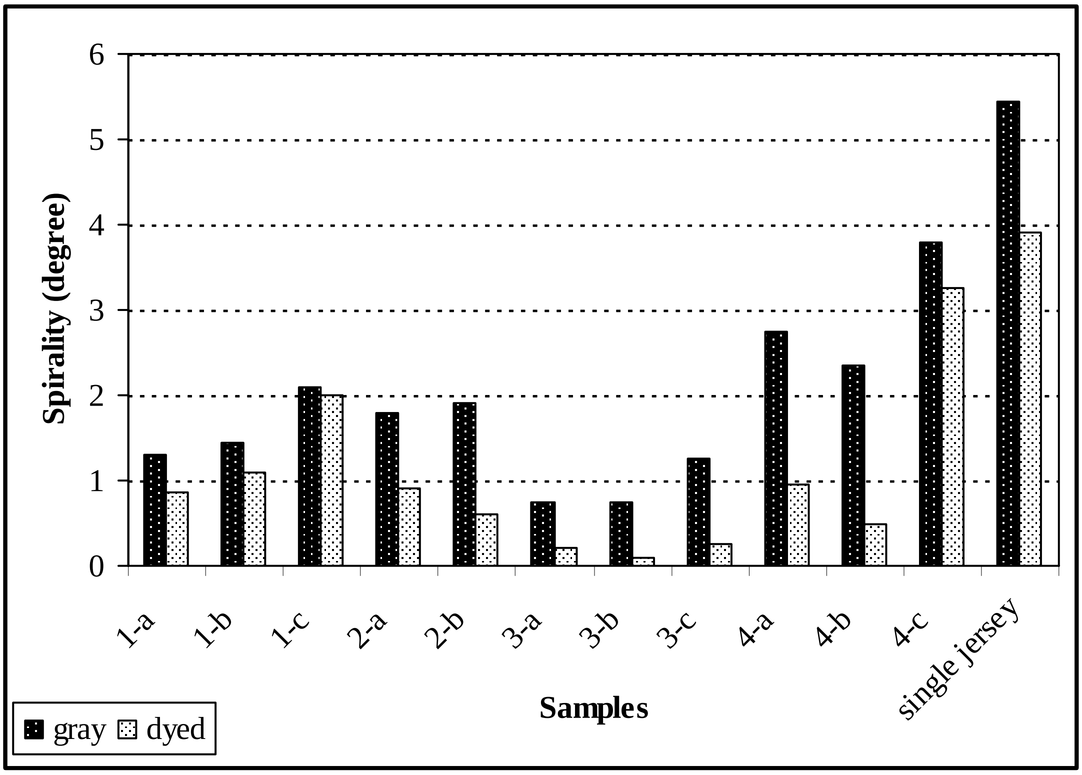


Figure 4.35 Spirality values of gray and dyed samples

The other result found from this figure is that the spirality values of dyed samples are lower than the spirality values of gray samples as explained before.

4.7.2 Statistical Analysis for Spirality

ANOVA test results showed that the number of tuck stitches has a significant effect on the spirality at %1 significance level.

According to the correlation analysis test results, correlations between the number of tuck stitches of samples and the spirality of samples are significant and negative for all groups. This means that an increase on the number of tuck stitches of fabrics causes decrease on the spirality values.

The correlation coefficients and the regression equations were given in Table 4.13.

Table 4.13 Correlation and regression results for spirality

Fabric	**Correlation (r) coefficient**		**Regression Equation**	
	Gray	**Dyed**	**Gray**	**Dyed**
1st group	-0.794**	-0.832**	S= -0.065 T + 5.286	S= -0.047 T + 3.909
2nd group	-0.788**	-0.852**	S= -0.023 T + 5.325	S= -0.020 T + 3.765
3rd group	-0.818**	-0.828**	S= -0.029 T + 4.719	S= -0.023 T + 3.212
4th group	-0.640**	-0.826**	S= -0.043 T + 5.285	S= -0.050 T + 4.129

CHAPTER 5

CONCLUSION

The conclusions found from this experimental study were summarized under six important titles as; the dimensional stability, the bursting strength, the abrasion resistance, the pilling resistance, the fabric thickness and the spirality. They are given as follows;

1. Dimensional Stability:

- An increase on the number of tuck stitches causes the increasing of lengthwise shrinkage values.
- An increase on the number of tuck stitches causes the decrease of shrinkage values or the increase of extension values for widthwise direction.
- The lengthwise shrinkage values of dyed fabrics are lower than the lengthwise shrinkage values of gray fabrics.
- When the number of tuck stitches in the same needle increases, the higher extension values are seen for widthwise direction.
- Single jersey has the lowest lengthwise shrinkage.
- The 3rd group -lacoste type fabrics have the lowest dimensional change values for widthwise in gray fabrics, and also have the lowest widthwise extension values in dyed fabrics.

2. Bursting Strength:

- An increase on the number of tuck stitches usually causes the decrease of bursting strength.

- When the tuck stitch gives effect of the miss stitch, an increase on the number of tuck stitches causes the increasing of bursting strength.

- The bursting strength values of fabrics having zigzag effect and less number of tuck stitches in the same needle are higher than the bursting strength values of other fabrics.

- The bursting strength values of dyed fabrics with tuck stitch are lower than the bursting strength values of gray fabrics with tuck stitch.

3. Abrasion Resistance:

- The abrasion resistance of fabrics having tuck stitches are higher than the abrasion resistance of single jersey.

- The abrasion resistance of clouqe fabrics having tuck stitches are lower than the abrasion resistance of the other fabrics having tuck stitches.

- The fabrics which resemble to double folded fabric have the highest abrasion resistance.

- The abrasion resistance values of dyed fabrics are higher than the abrasion resistance values of gray fabrics.

- An increase on the number of tuck stitches usually causes the increasing of abrasion resistance.

4. Pilling Resistance:

- Single jersey has the lowest pilling resistance.

- An increase on the number of tuck stitches increases the pilling resistance of fabrics.

- When the pattern size decreases, the pilling resistance increases.

- The smoothness fabrics with tuck stitch have the lower pilling resistance than the other fabrics with tuck stitch.

- The pilling resistance of dyed fabrics are lower than the pilling resistance of gray fabrics.

5. Fabric Thickness:

- The increasing of number of tuck stitches increases the fabric thickness.

6. Spirality:

- The increase on the number of tuck stitches decreases the spirality.

- The decrease on the pattern size reduces the spirality of fabrics having tuck stitches.

- The spirality values of dyed fabrics are lower than the spirality values of gray fabrics.

Recommendations

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

- These tests may be done on fabrics, which have different number and placement of tuck stitches out of samples in this study to be sure from the results of this study.

- These tests may be done on these samples, which have different tigthness factor to determine the effect of fabric tigthness.

- These samples may also be examined by other testing methods like as; air permeability, snagging, skewness, handle.

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

- It could be useful that use of different raw materials and properties like as silk, wool, viscouse to determine the dimensional change.

APPENDIX A
THE STATISTICAL ANALYSIS RESULTS
FOR THE EXPERIMENTAL STUDY

A1.1 Statistical Results in Lengthwise Dimensional Stability for 1st gray group

ANOVA

GLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1983,557	3	661,186	149,053	,000
Within Groups	88,718	20	4,436		
Total	2072,275	23			

Correlations

		TUCKS	GLDIMENS
TUCKS	Pearson Correlation	1	-,973**
	Sig. (2-tailed)		,000
	N	24	24
GLDIMENS	Pearson Correlation	-,973**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-6,064	,883		-6,865	,000
	TUCKS	-,355	,018	-,973	-19,587	,000

a. Dependent Variable: GLDIMENS

A1.2 Statistical Results in Lengthwise Dimensional Stability for 1st dyed group

ANOVA

DLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	447,063	3	149,021	36,654	,000
Within Groups	81,313	20	4,066		
Total	528,376	23			

Correlations

		TUCKS	DLDIMENS
TUCKS	Pearson Correlation	1	-,844**
	Sig. (2-tailed)		,000
	N	24	24
DLDIMENS	Pearson Correlation	-,844**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2,894	1,028		-2,816	,010
	TUCKS	-,156	,021	-,844	-7,374	,000

a. Dependent Variable: DLDIMENS

A2.1 Statistical Results in Lengthwise Dimensional Stability for 2nd gray group

ANOVA

GLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1714,987	2	857,494	160,175	,000
Within Groups	80,302	15	5,353		
Total	1795,290	17			

Correlations

		TUCKS	GLDIMENS
TUCKS	Pearson Correlation	1	-,874**
	Sig. (2-tailed)		,000
	N	18	18
GLDIMENS	Pearson Correlation	-,874**	1
	Sig. (2-tailed)	,000	
	N	18	18

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-7,706	2,064		-3,733	,002
	TUCKS	-,122	,017	-,874	-7,177	,000

a. Dependent Variable: GLDIMENS

A2.2 Statistical Results in Lengthwise Dimensional Stability for 2nd dyed group

ANOVA

DLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	416,906	2	208,453	89,588	,000
Within Groups	34,902	15	2,327		
Total	451,808	17			

Correlations

		TUCKS	DLDIMENS
TUCKS	Pearson Correlation	1	-,856**
	Sig. (2-tailed)		,000
	N	18	18
DLDIMENS	Pearson Correlation	-,856**	1
	Sig. (2-tailed)	,000	
	N	18	18

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3,295	1,100		-2,997	,009
	TUCKS	-,060	,009	-,856	-6,625	,000

a. Dependent Variable: DLDIMENS

A3.1 Statistical Results in Lengthwise Dimensional Stability for 3rd gray group

ANOVA

GLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1937,588	3	645,863	187,894	,000
Within Groups	68,748	20	3,437		
Total	2006,335	23			

Correlations

		TUCKS	GLDIMENS
TUCKS	Pearson Correlation	1	-,825**
	Sig. (2-tailed)		,000
	N	24	24
GLDIMENS	Pearson Correlation	-,825**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-10,362	1,985		-5,221	,000
	TUCKS	-,124	,018	-,825	-6,859	,000

a. Dependent Variable: GLDIMENS

A3.2 Statistical Results in Lengthwise Dimensional Stability for 3rd dyed group

ANOVA

DLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	623,626	3	207,875	126,740	,000
Within Groups	32,803	20	1,640		
Total	656,429	23			

Correlations

		TUCKS	DLDIMENS
TUCKS	Pearson Correlation	1	-,853**
	Sig. (2-tailed)		,000
	N	24	24
DLDIMENS	Pearson Correlation	-,853**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-4,662	1,050		-4,442	,000
	TUCKS	-,074	,010	-,853	-7,665	,000

a. Dependent Variable: DLDIMENS

A4.1 Statistical Results in Lengthwise Dimensional Stability for 4th gray group

ANOVA

GLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1951,974	3	650,658	277,583	,000
Within Groups	46,880	20	2,344		
Total	1998,854	23			

Correlations

		TUCKS	GLDIMENS
TUCKS	Pearson Correlation	1	-,929**
	Sig. (2-tailed)		,000
	N	24	24
GLDIMENS	Pearson Correlation	-,929**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-3,810	1,289		-2,956	,007
	TUCKS	-,319	,027	-,929	-11,793	,000

a. Dependent Variable: GLDIMENS

A4.2 Statistical Results in Lengthwise Dimensional Stability for 4th dyed group

ANOVA

DLDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	513,523	3	171,174	71,564	,000
Within Groups	47,838	20	2,392		
Total	561,361	23			

Correlations

		TUCKS	DLDIMENS
TUCKS	Pearson Correlation	1	-,956**
	Sig. (2-tailed)		,000
	N	24	24
DLDIMENS	Pearson Correlation	-,956**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-2,618	,543		-4,824	,000
	TUCKS	-,174	,011	-,956	-15,272	,000

a. Dependent Variable: DLDIMENS

A5.1 Statistical Results in Widthwise Dimensional Stability for 1st gray group

ANOVA

GWDIMENST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1234,764	3	411,588	146,115	,000
Within Groups	56,337	20	2,817		
Total	1291,101	23			

Correlations

		TUCKS	GWDIMENST
TUCKS	Pearson Correlation	1	,904**
	Sig. (2-tailed)		,000
	N	24	24
GWDIMENST	Pearson Correlation	,904**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-19,962	1,280		-15,594	,000
	TUCKS	,261	,026	,904	9,915	,000

a. Dependent Variable: GWDIMENST

A5.2 Statistical Results in Widthwise Dimensional Stability for 1st dyed group

ANOVA

DWDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	451,691	3	150,564	29,208	,000
Within Groups	103,097	20	5,155		
Total	554,788	23			

Correlations

		TUCKS	DWDIMENST
TUCKS	Pearson Correlation	1	,452*
	Sig. (2-tailed)		,026
	N	24	24
DWDIMENST	Pearson Correlation	,452*	1
	Sig. (2-tailed)	,026	
	N	24	24

*. Correlation is significant at the 0.05 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,423	6,843		,062	,952
	TUCKS	,053	,122	,108	,434	,670

a. Dependent Variable: DWDIMENST

A6.1 Statistical Results in Widthwise Dimensional Stability for 2nd gray group

ANOVA

GWDIMENST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	917,950	2	458,975	61,576	,000
Within Groups	111,806	15	7,454		
Total	1029,756	17			

Correlations

		TUCKS	GWDIMENST
TUCKS	Pearson Correlation	1	,727**
	Sig. (2-tailed)		,001
	N	18	18
GWDIMENST	Pearson Correlation	,727**	1
	Sig. (2-tailed)	,001	
	N	18	18

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-18,284	2,206		-8,287	,000
	TUCKS	,077	,018	,727	4,231	,001

a. Dependent Variable: GWDIMENST

A6.2 Statistical Results in Widthwise Dimensional Stability for 2nd dyed group

ANOVA

DWDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	368,594	2	184,297	55,565	,000
Within Groups	49,752	15	3,317		
Total	418,345	17			

Correlations

		TUCKS	DWDIMENST
TUCKS	Pearson Correlation	1	-,967**
	Sig. (2-tailed)		,000
	N	12	12
DWDIMENST	Pearson Correlation	-,967**	1
	Sig. (2-tailed)	,000	
	N	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	37,870	2,992		12,655	,000
	TUCKS	-,243	,020	-,967	-12,071	,000

a. Dependent Variable: DWDIMENST

A7.1 Statistical Results in Widthwise Dimensional Stability for 3rd gray group

ANOVA

GWDIMENST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1466,501	3	488,834	115,987	,000
Within Groups	84,291	20	4,215		
Total	1550,792	23			

Correlations

		TUCKS	GWDIMENST
TUCKS	Pearson Correlation	1	,933**
	Sig. (2-tailed)		,000
	N	24	24
GWDIMENST	Pearson Correlation	,933**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-17,955	1,110		-16,172	,000
	TUCKS	,124	,010	,933	12,188	,000

a. Dependent Variable: GWDIMENST

A7.2 Statistical Results in Widthwise Dimensional Stability for 3rd dyed group

ANOVA

DWDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	270,255	3	90,085	18,664	,000
Within Groups	96,533	20	4,827		
Total	366,787	23			

Correlations

		TUCKS	DWDIMENS
TUCKS	Pearson Correlation	1	,827**
	Sig. (2-tailed)		,000
	N	24	24
DWDIMENS	Pearson Correlation	,827**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-,870	,845		-1,030	,314
	TUCKS	,053	,008	,827	6,904	,000

a. Dependent Variable: DWDIMENS

A8.1 Statistical Results in Widthwise Dimensional Stability for 4th gray group

ANOVA

GWDIMENST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3100,876	3	1033,625	349,924	,000
Within Groups	59,077	20	2,954		
Total	3159,953	23			

Correlations

		TUCKS	GWDIMENST
TUCKS	Pearson Correlation	1	,711**
	Sig. (2-tailed)		,000
	N	24	24
GWDIMENST	Pearson Correlation	,711**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-24,766	3,083		-8,032	,000
	TUCKS	,307	,065	,711	4,745	,000

a. Dependent Variable: GWDIMENST

A8.2 Statistical Results in Widthwise Dimensional Stability for 4th dyed group

ANOVA

DWDIMENS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1151,609	3	383,870	73,272	,000
Within Groups	104,779	20	5,239		
Total	1256,388	23			

Correlations

		TUCKS	DWDIMENS
TUCKS	Pearson Correlation	1	,765**
	Sig. (2-tailed)		,000
	N	24	24
DWDIMENS	Pearson Correlation	,765**	1
	Sig. (2-tailed)	,000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-4,820	1,781		-2,706	,013
	TUCKS	,209	,037	,765	5,572	,000

a. Dependent Variable: DWDIMENS

A9.1 Statistical Results in Bursting Strength for 1st gray group

ANOVA

GBURSTSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	301525,9	3	100508,645	268,923	,000
Within Groups	5979,916	16	373,745		
Total	307505,8	19			

Correlations

		TUCKS	GBURSTSTR
TUCKS	Pearson Correlation	1	-,967**
	Sig. (2-tailed)		,000
	N	20	20
GBURSTSTR	Pearson Correlation	-,967**	1
	Sig. (2-tailed)	,000	
	N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	672,583	14,165		47,481	,000
	TUCKS	-4,719	,291	-,967	-16,212	,000

a. Dependent Variable: GBURSTSTR

A9.2 Statistical Results in Bursting Strength for 1st dyed group

ANOVA

DBURSTSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	472279,5	3	157426,494	577,707	,000
Within Groups	4360,036	16	272,502		
Total	476639,5	19			

Correlations

		TUCKS	DBURSTSTR
TUCKS	Pearson Correlation	1	-,967**
	Sig. (2-tailed)		,000
	N	20	20
DBURSTSTR	Pearson Correlation	-,967**	1
	Sig. (2-tailed)	,000	
	N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	704,468	17,807		39,561	,000
	TUCKS	-5,871	,366	-,967	-16,045	,000

a. Dependent Variable: DBURSTSTR

A10.1 Statistical Results in Bursting Strength for 2nd gray group

ANOVA

GBURSTSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18729,156	2	9364,578	16,579	,000
Within Groups	6778,000	12	564,833		
Total	25507,156	14			

Correlations

		TUCKS	GBURSTSTR
TUCKS	Pearson Correlation	1	,793**
	Sig. (2-tailed)		,000
	N	15	15
GBURSTSTR	Pearson Correlation	,793**	1
	Sig. (2-tailed)	,000	
	N	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	683,175	11,846		57,670	,000
	TUCKS	,458	,098	,793	4,685	,000

a. Dependent Variable: GBURSTSTR

A10.2 Statistical Results in Bursting Strength for 2nd dyed group

ANOVA

DBURSTSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	111188,3	2	55594,161	153,913	,000
Within Groups	4334,456	12	361,205		
Total	115522,8	14			

Correlations

		TUCK	DBURSTSTR
TUCK	Pearson Correlation	1	,976**
	Sig. (2-tailed)		,000
	N	10	10
DBURSTSTR	Pearson Correlation	,976**	1
	Sig. (2-tailed)	,000	
	N	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	82,680	41,117		2,011	,079
	TUCK	3,476	,277	,976	12,552	,000

a. Dependent Variable: DBURSTSTR

A11. Statistical Results in Bursting Strength for 3rd dyed group

ANOVA

DBURSTSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	89550,234	3	29850,078	50,510	,000
Within Groups	9455,536	16	590,971		
Total	99005,770	19			

Correlations

		TUCKS	DBURSTSTR
TUCKS	Pearson Correlation	1	-,755**
	Sig. (2-tailed)		,000
	N	20	20
DBURSTSTR	Pearson Correlation	-,755**	1
	Sig. (2-tailed)	,000	
	N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	699,956	19,626		35,664	,000
	TUCKS	-,876	,179	-,755	-4,879	,000

a. Dependent Variable: DBURSTSTR

A12.1 Statistical Results in Bursting Strength for 4th gray group

ANOVA

GBURSTSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	162824,3	3	54274,782	101,831	,000
Within Groups	8527,792	16	532,987		
Total	171352,1	19			

Correlations

		TUCKS	GBURSTSTR
TUCKS	Pearson Correlation	1	-,927**
	Sig. (2-tailed)		,000
	N	20	20
GBURSTSTR	Pearson Correlation	-,927**	1
	Sig. (2-tailed)	,000	
	N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	691,430	14,691		47,065	,000
	TUCKS	-3,231	,309	-,927	-10,468	,000

a. Dependent Variable: GBURSTSTR

A12.2 Statistical Results in Bursting Strength for 4th dyed group

ANOVA

DBURSTSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	329446,5	3	109815,490	224,830	,000
Within Groups	7814,992	16	488,437		
Total	337261,5	19			

Correlations

		TUCKS	DBURSTSTR
TUCKS	Pearson Correlation	1	-,943**
	Sig. (2-tailed)		,000
	N	20	20
DBURSTSTR	Pearson Correlation	-,943**	1
	Sig. (2-tailed)	,000	
	N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	701,989	18,217		38,535	,000
	TUCKS	-4,614	,383	-,943	-12,054	,000

a. Dependent Variable: DBURSTSTR

A13.1 Statistical Results in Abrasion Resistance for 1st gray group

ANOVA

GABRASION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	76,051	3	25,350	32,932	,000
Within Groups	6,158	8	,770		
Total	82,209	11			

Correlations

		TUCK	GABRASION
TUCK	Pearson Correlation	1	,831**
	Sig. (2-tailed)		,005
	N	9	9
GABRASION	Pearson Correlation	,831**	1
	Sig. (2-tailed)	,005	
	N	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4,597	1,844		2,493	,041
	TUCK	,130	,033	,831	3,955	,005

a. Dependent Variable: GABRASION

A13.2 Statistical Results in Abrasion Resistance for 1st dyed group

ANOVA

DABRASION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16,870	3	5,623	12,828	,002
Within Groups	3,507	8	,438		
Total	20,376	11			

Correlations

		TUCK	DABRASION
TUCK	Pearson Correlation	1	,807**
	Sig. (2-tailed)		,009
	N	9	9
DABRASION	Pearson Correlation	,807**	1
	Sig. (2-tailed)	,009	
	N	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,954	1,879		2,105	,073
	TUCK	,121	,033	,807	3,609	,009

a. Dependent Variable: DABRASION

A14. Statistical Results in Abrasion Resistance for 2nd gray group

ANOVA

GABRASION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	86,232	2	43,116	52,477	,000
Within Groups	4,930	6	,822		
Total	91,161	8			

Correlations

		TUCKS	GABRASION
TUCKS	Pearson Correlation	1	-,970**
	Sig. (2-tailed)		,000
	N	9	9
GABRASION	Pearson Correlation	-,970**	1
	Sig. (2-tailed)	,000	
	N	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	16,897	,500		33,785	,000
	TUCKS	-,043	,004	-,970	-10,479	,000

a. Dependent Variable: GABRASION

A15.1 Statistical Results in Abrasion Resistance for 3rd gray group

ANOVA

GABRASION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	86,291	3	28,764	50,663	,000
Within Groups	4,542	8	,568		
Total	90,833	11			

Correlations

		TUCKS	GABRASION
TUCKS	Pearson Correlation	1	-,926**
	Sig. (2-tailed)		,000
	N	12	12
GABRASION	Pearson Correlation	-,926**	1
	Sig. (2-tailed)	,000	
	N	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	17,703	,594		29,799	,000
	TUCKS	-,042	,005	-,926	-7,732	,000

a. Dependent Variable: GABRASION

A15.2 Statistical Results in Abrasion Resistance for 3rd dyed group

ANOVA

DABRASION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10,355	3	3,452	10,488	,004
Within Groups	2,633	8	,329		
Total	12,988	11			

Correlations

		TUCK	DABRASION
TUCK	Pearson Correlation	1	-,916**
	Sig. (2-tailed)		,001
	N	9	9
DABRASION	Pearson Correlation	-,916**	1
	Sig. (2-tailed)	,001	
	N	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	13,310	,600		22,182	,000
	TUCK	-,029	,005	-,916	-6,051	,001

a. Dependent Variable: DABRASION

A16.1 Statistical Results in Abrasion Resistance for 4th gray group

ANOVA

GABRASION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	57,656	3	19,219	33,604	,000
Within Groups	4,575	8	,572		
Total	62,231	11			

Correlations

		TUCKS	GABRASION
TUCKS	Pearson Correlation	1	-,714**
	Sig. (2-tailed)		,009
	N	12	12
GABRASION	Pearson Correlation	-,714**	1
	Sig. (2-tailed)	,009	
	N	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	15,679	,904		17,344	,000
	TUCKS	-,061	,019	-,714	-3,224	,009

a. Dependent Variable: GABRASION

A16.2 Statistical Results in Abrasion Resistance for 4th dyed group

ANOVA

DABRASION

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17,674	3	5,891	10,154	,004
Within Groups	4,642	8	,580		
Total	22,316	11			

Correlations

		TUCKS	DABRASION
TUCKS	Pearson Correlation	1	-,825**
	Sig. (2-tailed)		,006
	N	9	9
DABRASION	Pearson Correlation	-,825**	1
	Sig. (2-tailed)	,006	
	N	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10,386	,438		23,708	,000
	TUCKS	-,045	,012	-,825	-3,858	,006

a. Dependent Variable: DABRASION

A17.1 Statistical Results in Pilling Resistance for 1st gray group

ANOVA

GPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	41,222	3	13,741	8,794	,000
Within Groups	50,000	32	1,563		
Total	91,222	35			

Correlations

		TUCKS	GPILLING
TUCKS	Pearson Correlation	1	-,623**
	Sig. (2-tailed)		,000
	N	36	36
GPILLING	Pearson Correlation	-,623**	1
	Sig. (2-tailed)	,000	
	N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13,340	,409		32,618	,000
	TUCKS	-,039	,008	-,623	-4,639	,000

a. Dependent Variable: GPILLING

A17.2 Statistical Results in Pilling Resistance for 1st dyed group

ANOVA

DPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	63,667	3	21,222	5,680	,003
Within Groups	119,556	32	3,736		
Total	183,222	35			

Correlations

		TUCKS	DPILLING
TUCKS	Pearson Correlation	1	-,582**
	Sig. (2-tailed)		,000
	N	36	36
DPILLING	Pearson Correlation	-,582**	1
	Sig. (2-tailed)	,000	
	N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	14,866	,602		24,686	,000
	TUCKS	-,052	,012	-,582	-4,175	,000

a. Dependent Variable: DPILLING

A18.1 Statistical Results in Pilling Resistance for 2nd gray group

ANOVA

GPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	42,667	2	21,333	10,378	,001
Within Groups	49,333	24	2,056		
Total	92,000	26			

Correlations

		TUCKS	GPILLING
TUCKS	Pearson Correlation	1	-,661**
	Sig. (2-tailed)		,000
	N	27	27
GPILLING	Pearson Correlation	-,661**	1
	Sig. (2-tailed)	,000	
	N	27	27

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	13,009	,470		27,650	,000
	TUCKS	-,017	,004	-,661	-4,405	,000

a. Dependent Variable: GPILLING

A18.2 Statistical Results in Pilling Resistance for 2nd dyed group

ANOVA

DPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	43,556	2	21,778	6,663	,005
Within Groups	78,444	24	3,269		
Total	122,000	26			

Correlations

		TUCKS	DPILLING
TUCKS	Pearson Correlation	1	-,595**
	Sig. (2-tailed)		,001
	N	27	27
DPILLING	Pearson Correlation	-,595**	1
	Sig. (2-tailed)	,001	
	N	27	27

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	14,735	,581		25,380	,000
	TUCKS	-,018	,005	-,595	-3,697	,001

a. Dependent Variable: DPILLING

A19.1 Statistical Results in Pilling Resistance for 3rd gray group

ANOVA

GPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	210,972	3	70,324	33,421	,000
Within Groups	67,333	32	2,104		
Total	278,306	35			

Correlations

		TUCKS	GPILLING
TUCKS	Pearson Correlation	1	-,888**
	Sig. (2-tailed)		,000
	N	27	27
GPILLING	Pearson Correlation	-,888**	1
	Sig. (2-tailed)	,000	
	N	27	27

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13,017	,462		28,204	,000
	TUCKS	-,055	,006	-,888	-9,676	,000

a. Dependent Variable: GPILLING

A19.2 Statistical Results in Pilling Resistance for 3rd dyed group

ANOVA

DPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	237,111	3	79,037	25,348	,000
Within Groups	99,778	32	3,118		
Total	336,889	35			

Correlations

		TUCKS	DPILLING
TUCKS	Pearson Correlation	1	-,838**
	Sig. (2-tailed)		,000
	N	27	27
DPILLING	Pearson Correlation	-,838**	1
	Sig. (2-tailed)	,000	
	N	27	27

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	14,662	,595		24,635	,000
	TUCKS	-,057	,007	-,838	-7,690	,000

a. Dependent Variable: DPILLING

A20.1 Statistical Results in Pilling Resistance for 4th gray group

ANOVA

GPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	31,222	3	10,407	3,422	,029
Within Groups	97,333	32	3,042		
Total	128,556	35			

Correlations

		TUCKS	GPILLING
TUCKS	Pearson Correlation	1	-,483**
	Sig. (2-tailed)		,003
	N	36	36
GPILLING	Pearson Correlation	-,483**	1
	Sig. (2-tailed)	,003	
	N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	12,970	,509		25,502	,000
	TUCKS	-,034	,011	-,483	-3,220	,003

a. Dependent Variable: GPILLING

A20.2 Statistical Results in Pilling Resistance for 4th dyed group

ANOVA

DPILLING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	67,639	3	22,546	6,149	,002
Within Groups	117,333	32	3,667		
Total	184,972	35			

Correlations

		TUCKS	DPILLING
TUCKS	Pearson Correlation	1	-,565**
	Sig. (2-tailed)		,000
	N	36	36
DPILLING	Pearson Correlation	-,565**	1
	Sig. (2-tailed)	,000	
	N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	14,377	,575		24,998	,000
	TUCKS	-,048	,012	-,565	-3,991	,000

a. Dependent Variable: DPILLING

A21.1 Statistical Results in Thickness for 1st gray group

ANOVA

GTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,081	3	,027	13,933	,000
Within Groups	,070	36	,002		
Total	,152	39			

Correlations

		TUCKS	GTHICKNESS
TUCKS	Pearson Correlation	1	,733**
	Sig. (2-tailed)		,000
	N	40	40
GTHICKNESS	Pearson Correlation	,733**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,441	,013		33,908	,000
	TUCKS	,002	,000	,733	6,639	,000

a. Dependent Variable: GTHICKNESS

A21.2 Statistical Results in Thickness for 1st dyed group

ANOVA

DTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,033	3	,011	7,862	,000
Within Groups	,050	36	,001		
Total	,083	39			

Correlations

		TUCKS	DTHICKNESS
TUCKS	Pearson Correlation	1	,626**
	Sig. (2-tailed)		,000
	N	40	40
DTHICKNESS	Pearson Correlation	,626**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,445	,011		40,341	,000
	TUCKS	,001	,000	,626	4,944	,000

a. Dependent Variable: DTHICKNESS

A22.1 Statistical Results in Thickness for 2nd gray group

ANOVA

GTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,155	2	,077	337,493	,000
Within Groups	,006	27	,000		
Total	,161	29			

Correlations

		TUCKS	GTHICKNESS
TUCKS	Pearson Correlation	1	,934**
	Sig. (2-tailed)		,000
	N	30	30
GTHICKNESS	Pearson Correlation	,934**	1
	Sig. (2-tailed)	,000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,448	,008		53,235	,000
	TUCKS	,001	,000	,934	13,786	,000

a. Dependent Variable: GTHICKNESS

A22.2 Statistical Results in Thickness for 2nd dyed group

ANOVA

DTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,237	2	,118	280,642	,000
Within Groups	,011	27	,000		
Total	,248	29			

Correlations

		TUCKS	DTHICKNESS
TUCKS	Pearson Correlation	1	,976**
	Sig. (2-tailed)		,000
	N	30	30
DTHICKNESS	Pearson Correlation	,976**	1
	Sig. (2-tailed)	,000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,445	,006		69,522	,000
	TUCKS	,001	,000	,976	23,532	,000

a. Dependent Variable: DTHICKNESS

A23.1 Statistical Results in Thickness for 3rd gray group

ANOVA

GTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,337	3	,112	549,596	,000
Within Groups	,007	36	,000		
Total	,344	39			

Correlations

		TUCKS	GTHICKNESS
TUCKS	Pearson Correlation	1	,803**
	Sig. (2-tailed)		,000
	N	40	40
GTHICKNESS	Pearson Correlation	,803**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,456	,016		28,218	,000
	TUCKS	,001	,000	,803	8,301	,000

a. Dependent Variable: GTHICKNESS

A23.2 Statistical Results in Thickness for 3rd dyed group

ANOVA

DTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,238	3	,079	240,789	,000
Within Groups	,012	36	,000		
Total	,250	39			

Correlations

		TUCK	DTHICKNESS
TUCK	Pearson Correlation	1	,912**
	Sig. (2-tailed)		,000
	N	40	40
DTHICKNESS	Pearson Correlation	,912**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,459	,010		48,295	,000
	TUCK	,001	,000	,912	13,679	,000

a. Dependent Variable: DTHICKNESS

A24.1 Statistical Results in Thickness for 4th gray group

ANOVA

GTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,065	3	,022	22,915	,000
Within Groups	,034	36	,001		
Total	,100	39			

Correlations

		TUCKS	GTHICKNESS
TUCKS	Pearson Correlation	1	,805**
	Sig. (2-tailed)		,000
	N	40	40
GTHICKNESS	Pearson Correlation	,805**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,444	,009		51,573	,000
	TUCKS	,002	,000	,805	8,360	,000

a. Dependent Variable: GTHICKNESS

A24.2 Statistical Results in Thickness for 4th dyed group

ANOVA

DTHICKNESS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,073	3	,024	14,281	,000
Within Groups	,061	36	,002		
Total	,135	39			

Correlations

		TUCKS	DTHICKNESS
TUCKS	Pearson Correlation	1	,736**
	Sig. (2-tailed)		,000
	N	40	40
DTHICKNESS	Pearson Correlation	,736**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,443	,011		38,792	,000
	TUCKS	,002	,000	,736	6,708	,000

a. Dependent Variable: DTHICKNESS

A25.1 Statistical Results in Spirality for 1st gray group

ANOVA

GSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	113,825	3	37,942	22,410	,000
Within Groups	60,950	36	1,693		
Total	174,775	39			

Correlations

		TUCKS	GSPIRALITY
TUCKS	Pearson Correlation	1	-,794**
	Sig. (2-tailed)		,000
	N	40	40
GSPIRALITY	Pearson Correlation	-,794**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	5,286	,394		13,405	,000
	TUCKS	-,065	,008	-,794	-8,062	,000

a. Dependent Variable: GSPIRALITY

A25.2 Statistical Results in Spirality for 1st dyed group

ANOVA

DSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	57,369	3	19,123	27,731	,000
Within Groups	24,825	36	,690		
Total	82,194	39			

Correlations

		TUCKS	DSPIRALITY
TUCKS	Pearson Correlation	1	-,832**
	Sig. (2-tailed)		,000
	N	40	40
DSPIRALITY	Pearson Correlation	-,832**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3,909	,247		15,811	,000
	TUCKS	-,047	,005	-,832	-9,232	,000

a. Dependent Variable: DSPIRALITY

A26.1 Statistical Results in Spirality for 2nd gray group

ANOVA

GSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	86,450	2	43,225	25,248	,000
Within Groups	46,225	27	1,712		
Total	132,675	29			

Correlations

		TUCKS	GSPIRALITY
TUCKS	Pearson Correlation	1	-,788**
	Sig. (2-tailed)		,000
	N	30	30
GSPIRALITY	Pearson Correlation	-,788**	1
	Sig. (2-tailed)	,000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5,325	,416		12,814	,000
	TUCKS	-,023	,003	-,788	-6,773	,000

a. Dependent Variable: GSPIRALITY

A26.2 Statistical Results in Spirality for 2nd dyed group

ANOVA

DSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	66,200	2	33,100	48,048	,000
Within Groups	18,600	27	,689		
Total	84,800	29			

Correlations

		TUCKS	DSPIRALITY
TUCKS	Pearson Correlation	1	-,852**
	Sig. (2-tailed)		,000
	N	30	30
DSPIRALITY	Pearson Correlation	-,852**	1
	Sig. (2-tailed)	,000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,765	,283		13,308	,000
	TUCKS	-,020	,002	-,852	-8,594	,000

a. Dependent Variable: DSPIRALITY

A27.1 Statistical Results in Spirality for 3rd gray group

ANOVA

GSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	155,800	3	51,933	56,483	,000
Within Groups	33,100	36	,919		
Total	188,900	39			

Correlations

		TUCKS	GSPIRALITY
TUCKS	Pearson Correlation	1	-,818**
	Sig. (2-tailed)		,000
	N	40	40
GSPIRALITY	Pearson Correlation	-,818**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4,719	,365		12,912	,000
	TUCKS	-,029	,003	-,818	-8,775	,000

a. Dependent Variable: GSPIRALITY

A27.2 Statistical Results in Spirality for 3rd dyed group

ANOVA

DSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	103,719	3	34,573	118,254	,000
Within Groups	10,525	36	,292		
Total	114,244	39			

Correlations

		TUCKS	DSPIRALITY
TUCKS	Pearson Correlation	1	-,828**
	Sig. (2-tailed)		,000
	N	40	40
DSPIRALITY	Pearson Correlation	-,828**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,212	,278		11,572	,000
	TUCKS	-,023	,003	-,828	-9,088	,000

a. Dependent Variable: DSPIRALITY

A28.1 Statistical Results in Spirality for 4th gray group

ANOVA

GSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	57,469	3	19,156	9,926	,000
Within Groups	69,475	36	1,930		
Total	126,944	39			

Correlations

		TUCKS	GSPIRALITY
TUCKS	Pearson Correlation	1	-,640**
	Sig. (2-tailed)		,000
	N	40	40
GSPIRALITY	Pearson Correlation	-,640**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5,285	,398		13,280	,000
	TUCKS	-,043	,008	-,640	-5,139	,000

a. Dependent Variable: GSPIRALITY

A28.2 Statistical Results in Spirality for 4th dyed group

ANOVA

DSPIRALITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	84,350	3	28,117	52,582	,000
Within Groups	19,250	36	,535		
Total	103,600	39			

Correlations

		TUCKS	DSPIRALITY
TUCKS	Pearson Correlation	1	-,826**
	Sig. (2-tailed)		,000
	N	40	40
DSPIRALITY	Pearson Correlation	-,826**	1
	Sig. (2-tailed)	,000	
	N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4,129	,264		15,659	,000
	TUCKS	-,050	,006	-,826	-9,042	,000

a. Dependent Variable: DSPIRALITY

APPENDIX B

DIMENSIONAL STABILITY DIAGRAMS FOR SAMPLES

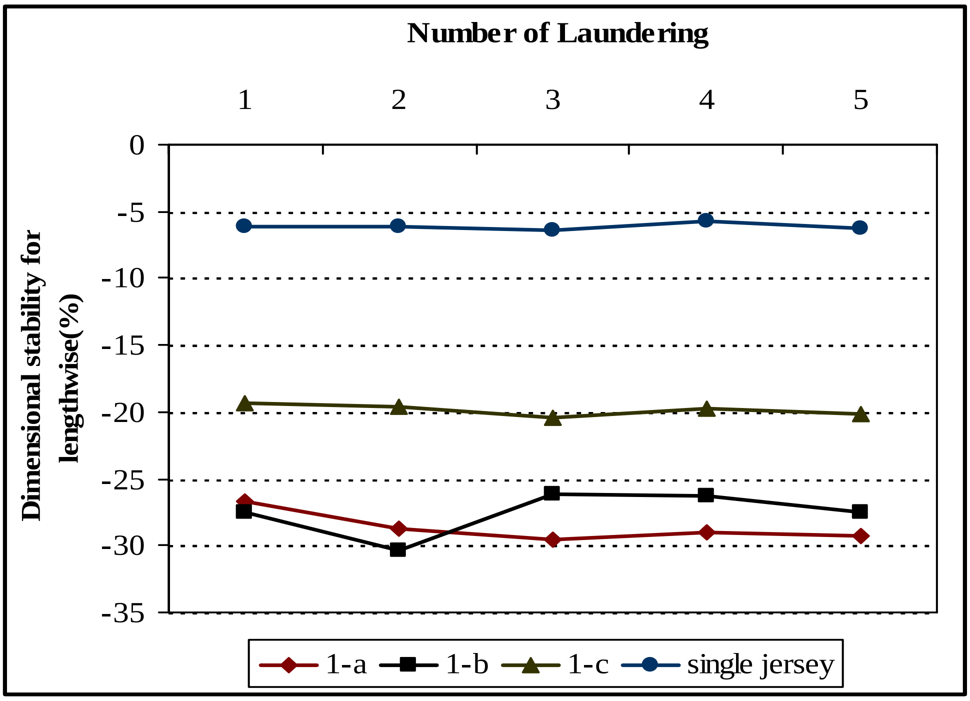


Figure B.1 Dimensional stability diagram for 1st group gray samples

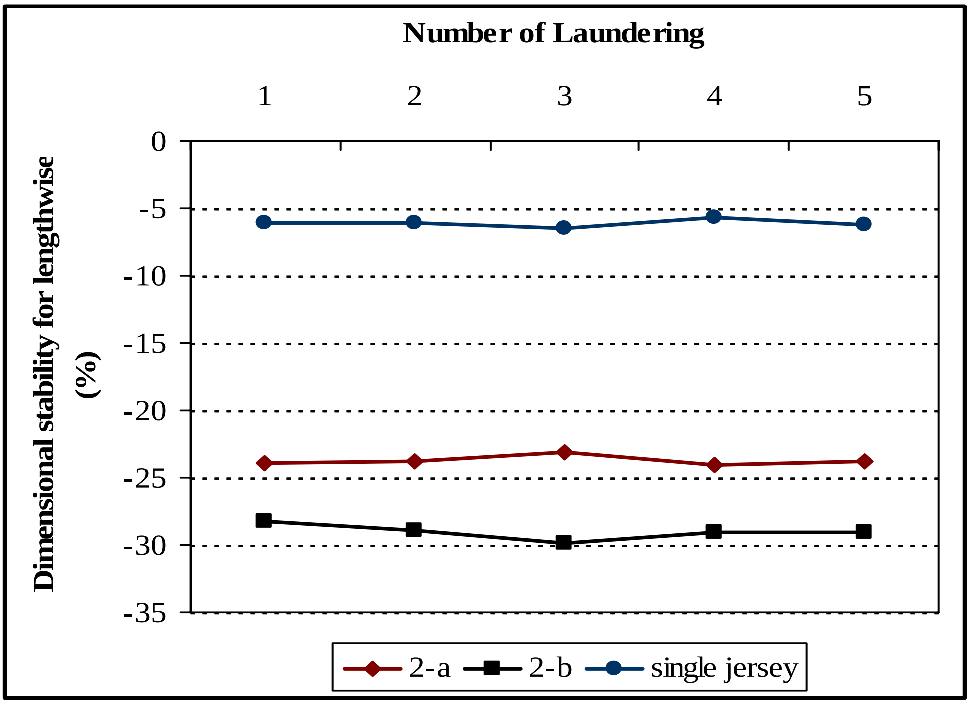


Figure B.2 Dimensional stability diagram for 2nd group gray samples

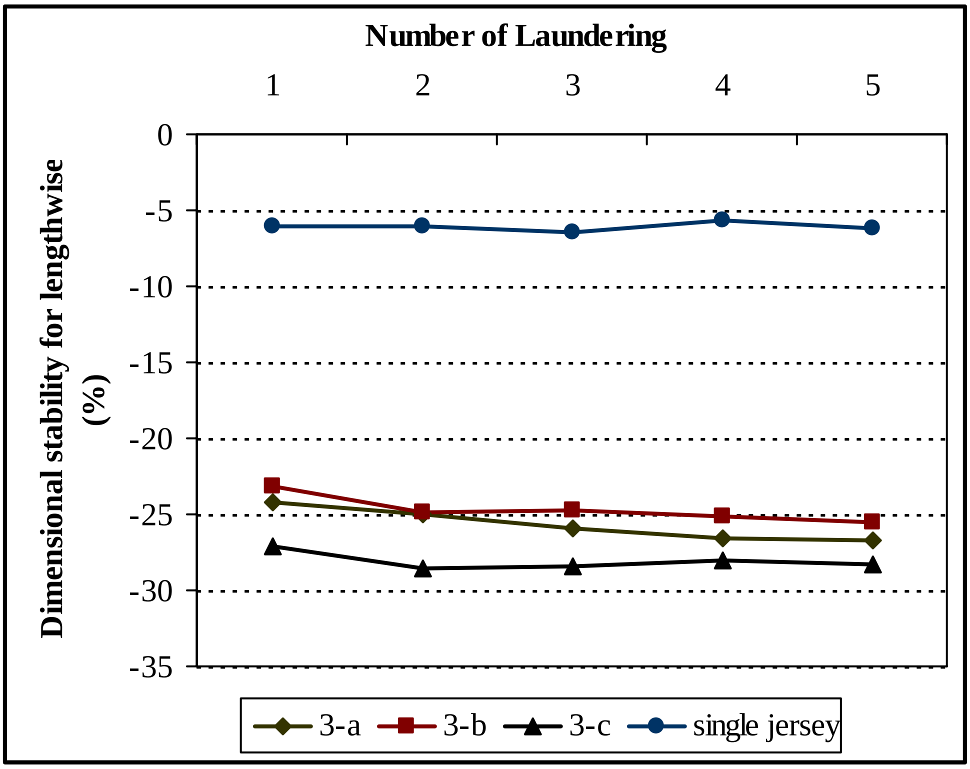


Figure B.3 Dimensional stability diagram for 3rd group gray samples

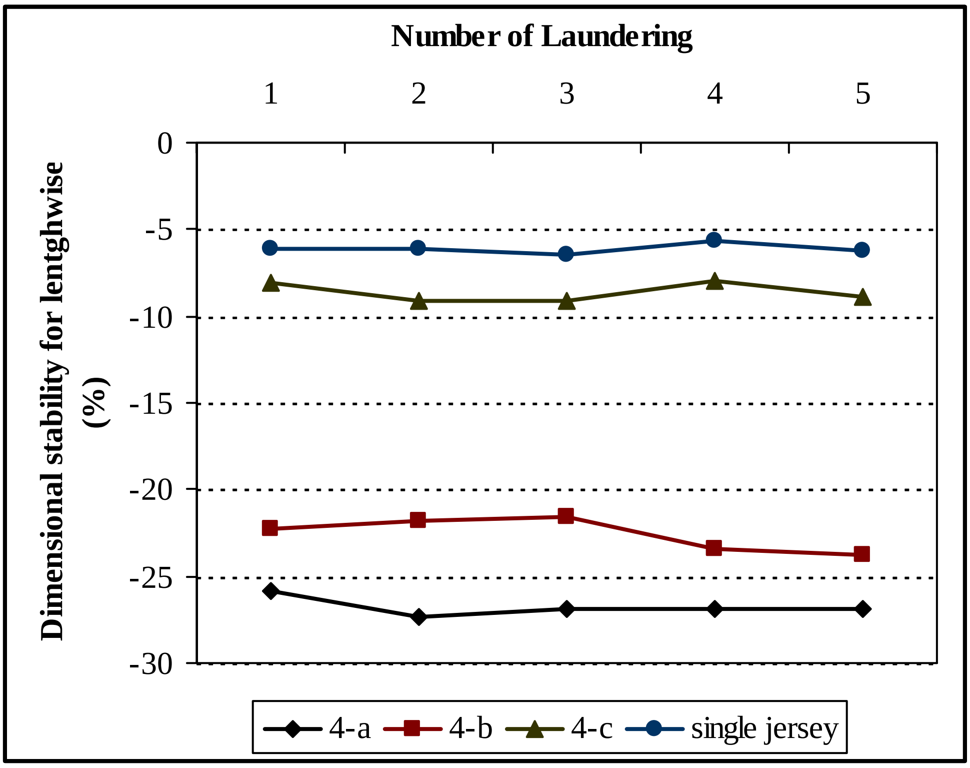


Figure B.4 Dimensional stability diagram for 4th group gray samples

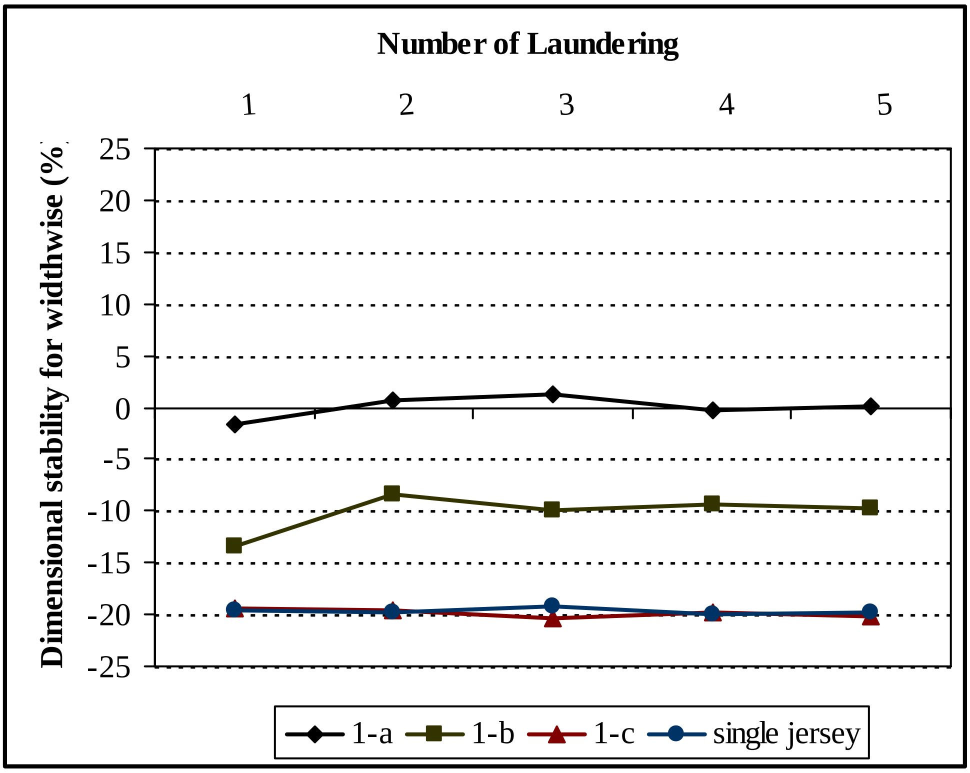


Figure B.5 Dimensional stability diagram for 1st group gray samples

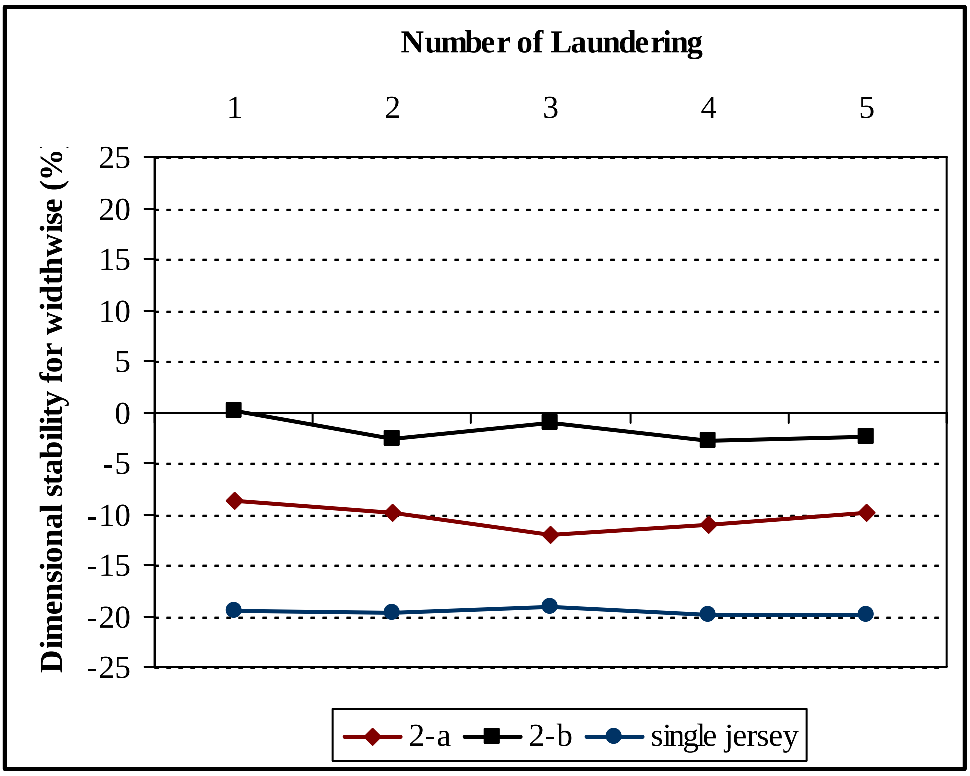


Figure B.6 Dimensional stability diagram for 2nd group gray samples

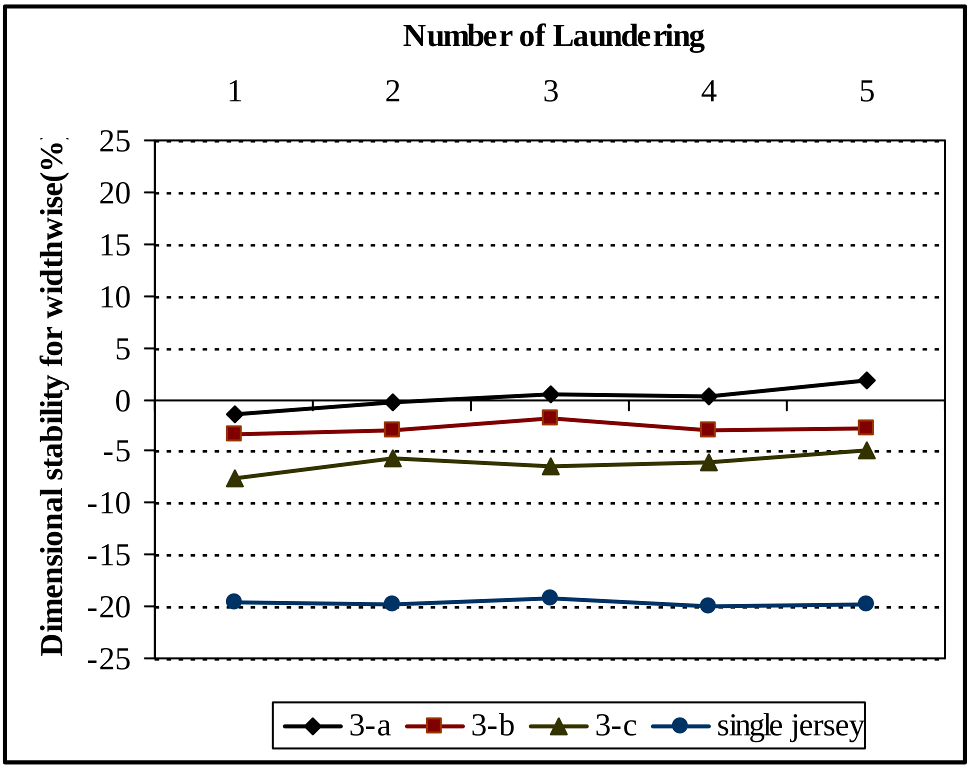


Figure B.7 Dimensional stability diagram for 3rd group gray samples

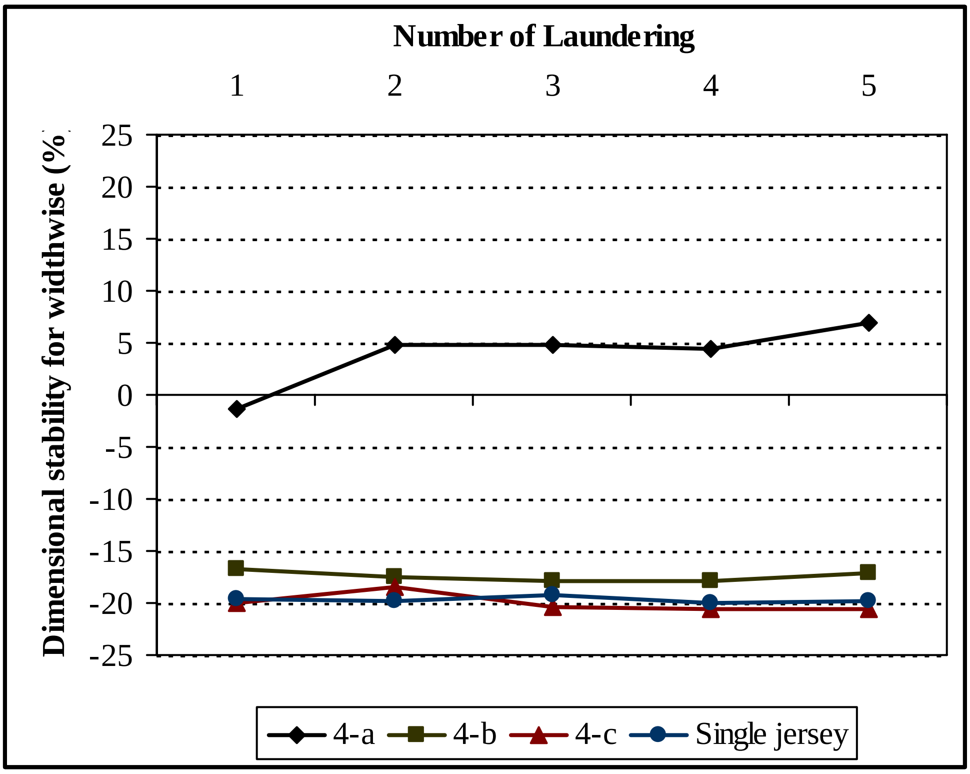


Figure B.8 Dimensional stability diagram for 4th group gray samples

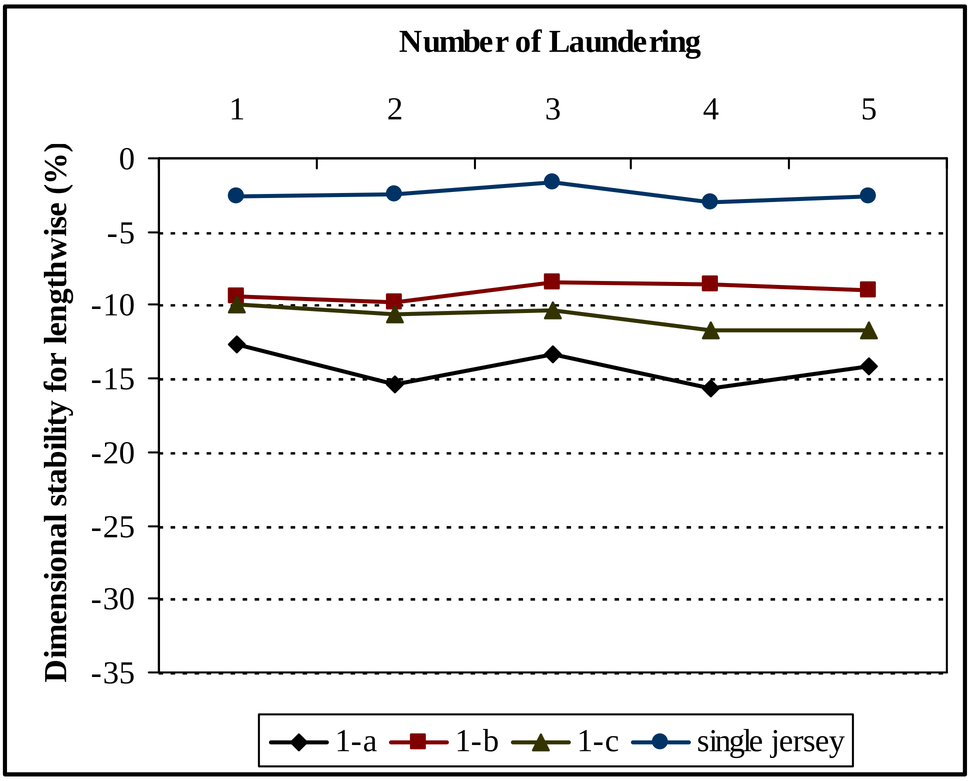


Figure B.9 Dimensional stability diagram for 1st group dyed samples

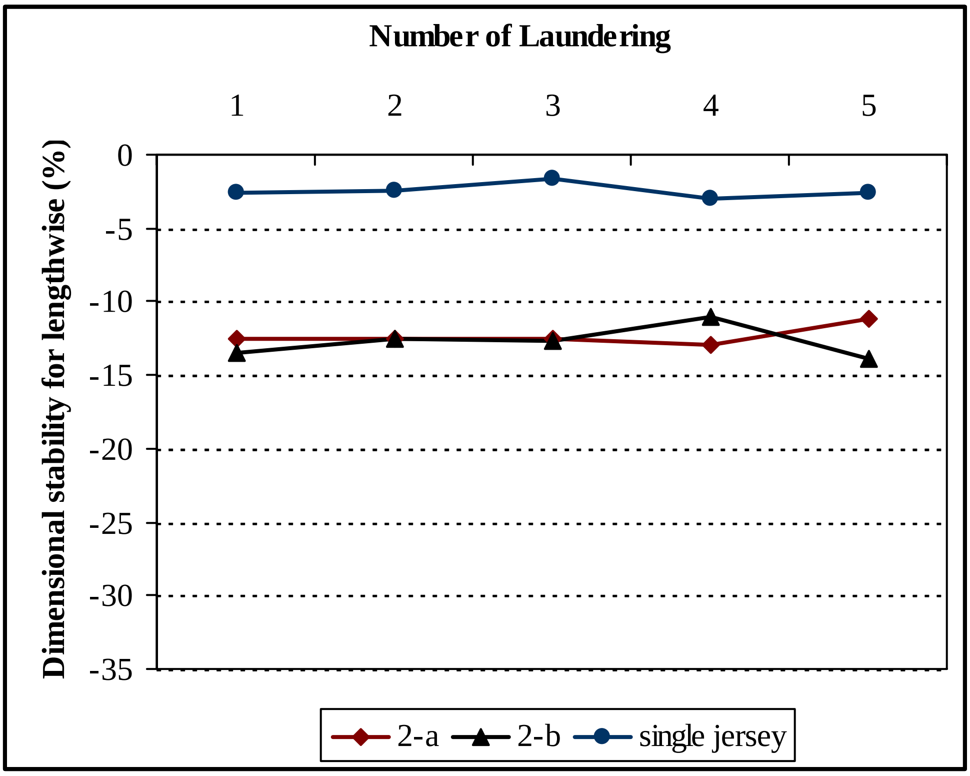


Figure B.10 Dimensional stability diagram for 2nd group dyed samples

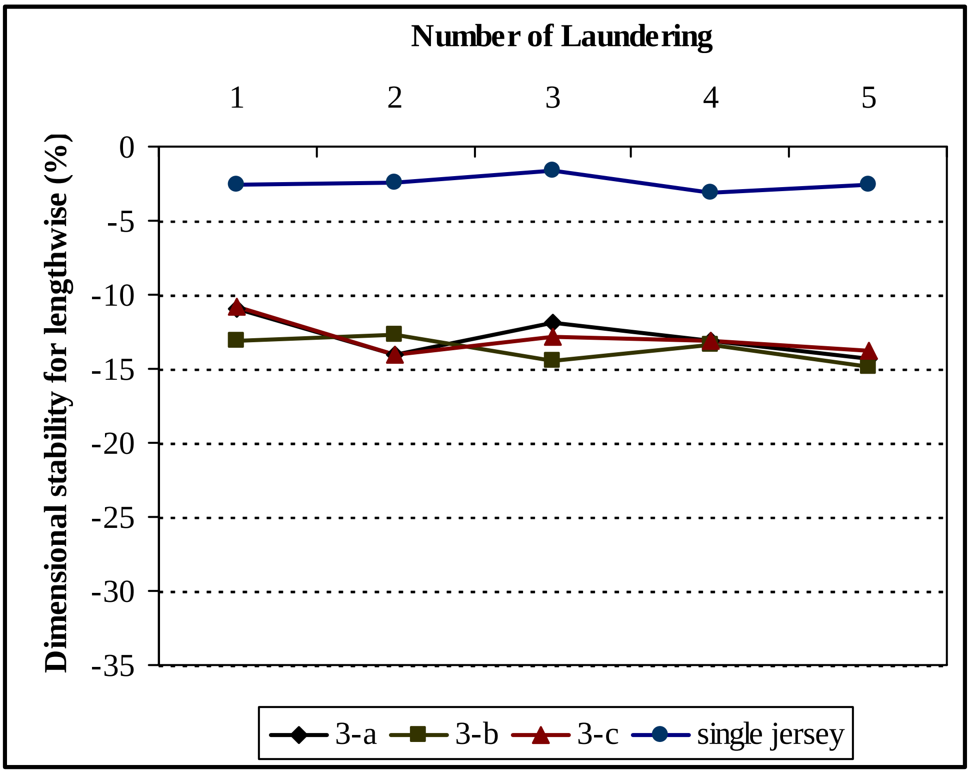


Figure B.11 Dimensional stability diagram for 3rd group dyed samples

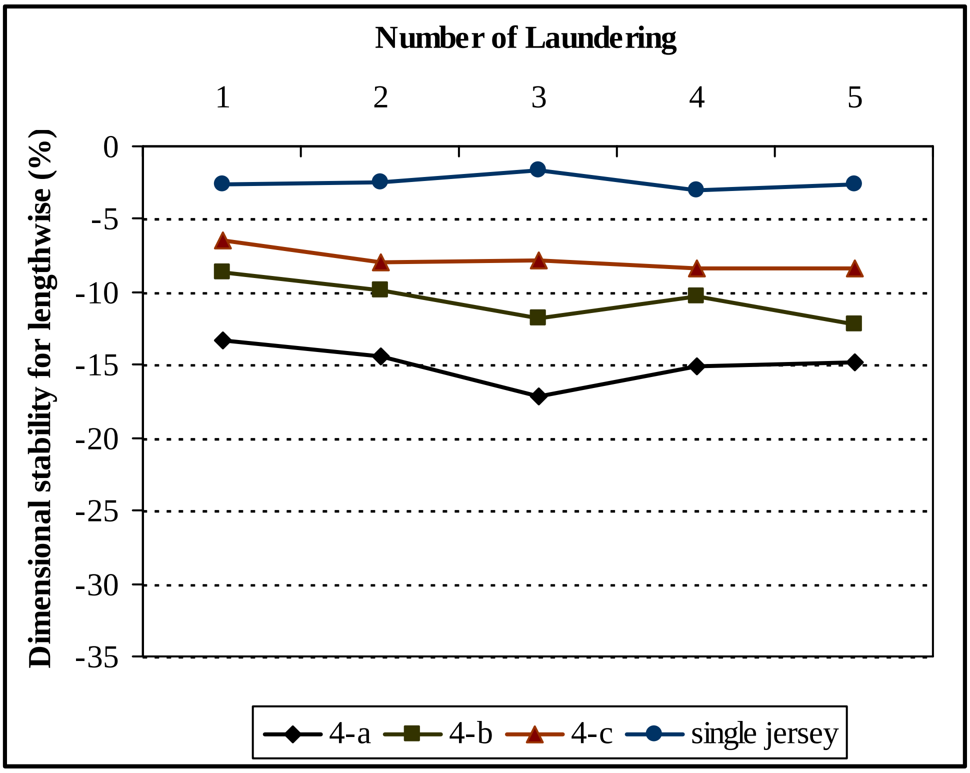


Figure B.12 Dimensional stability diagram for 4th group dyed samples

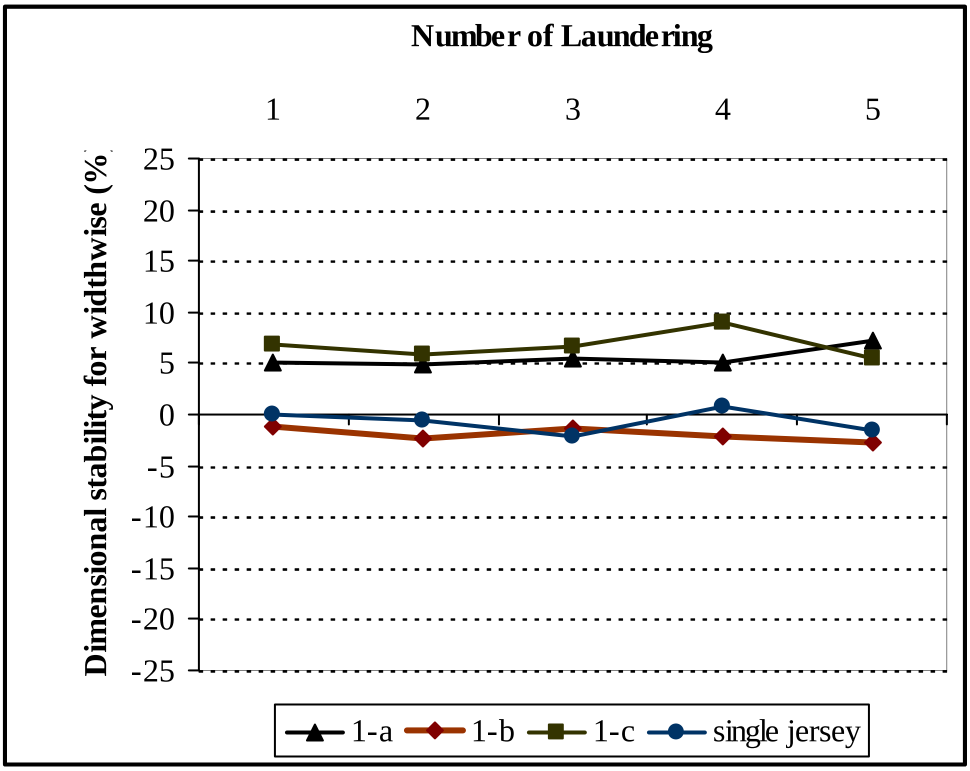


Figure B.13 Dimensional stability diagram for 1st group dyed samples

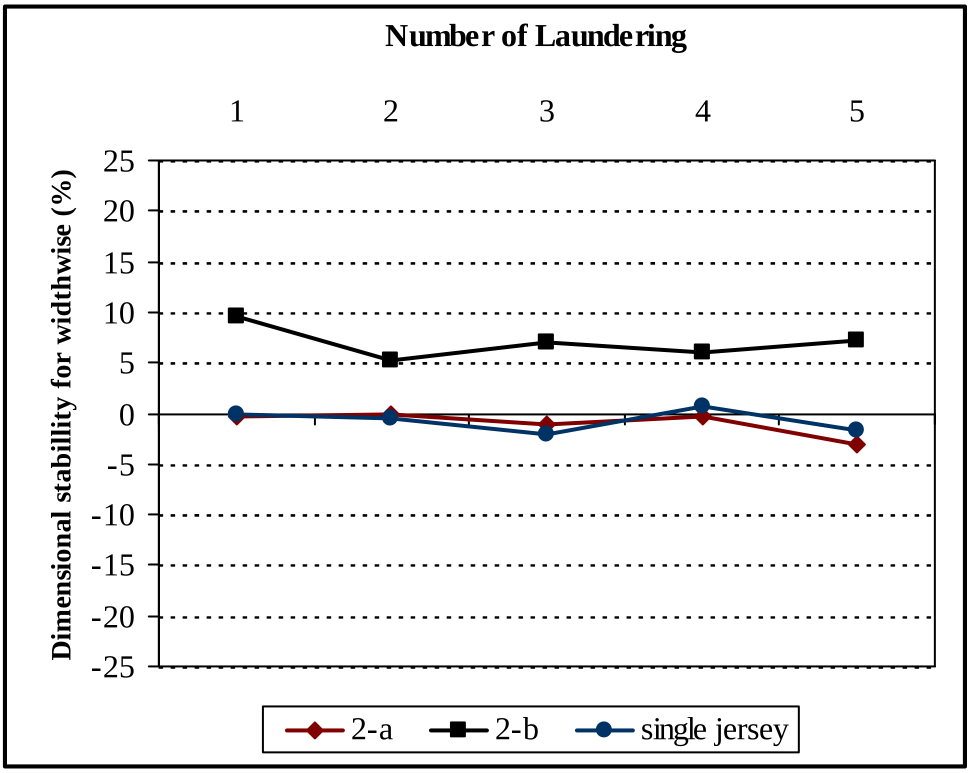


Figure B.14 Dimensional stability diagram for 2nd group dyed samples

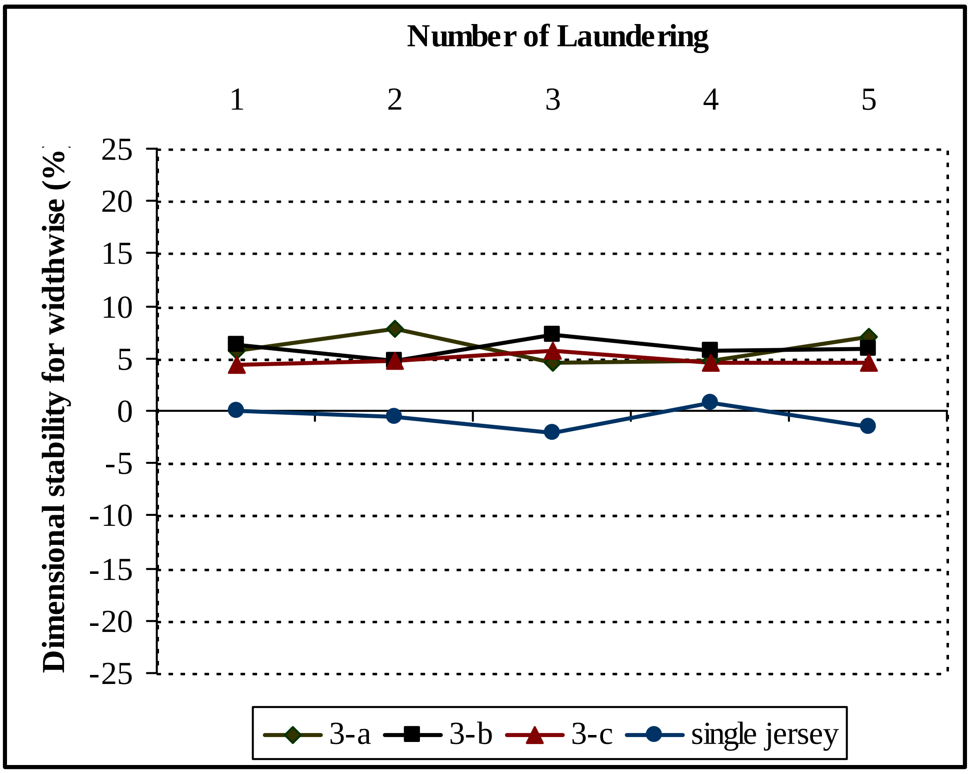


Figure B.15 Dimensional stability diagram for 3rd group dyed samples

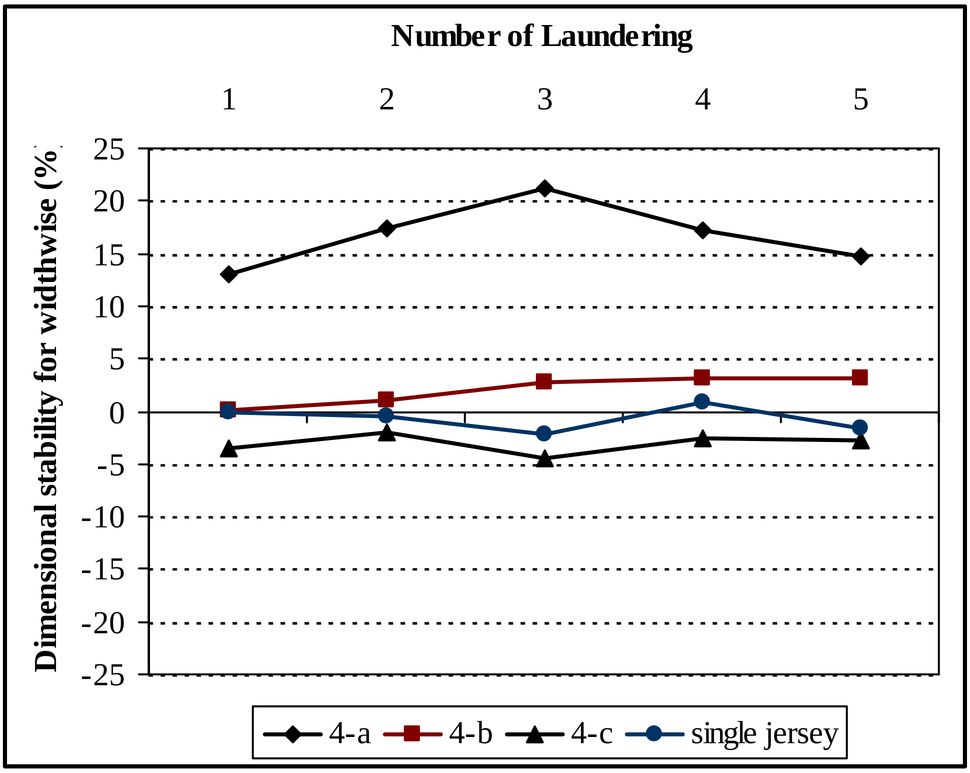


Figure B.16 Dimensional stability diagram for 4th group dyed samples

APPENDIX C

ABRASION RESISTANCE DIAGRAMS FOR SAMPLES

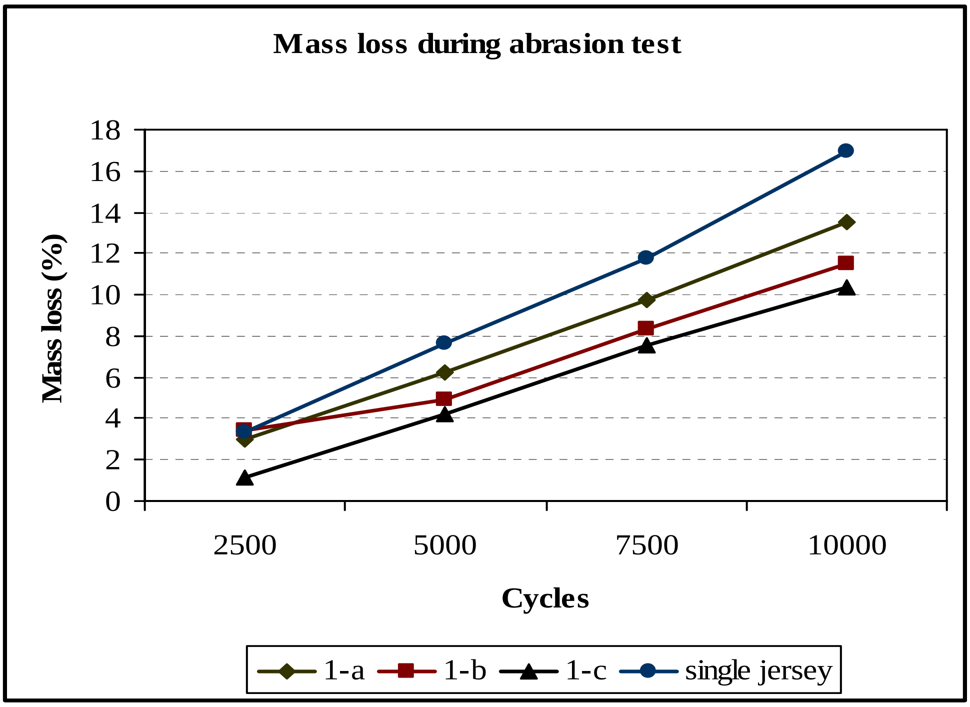


Figure C.1 Mass loss diagram for 1st group gray samples

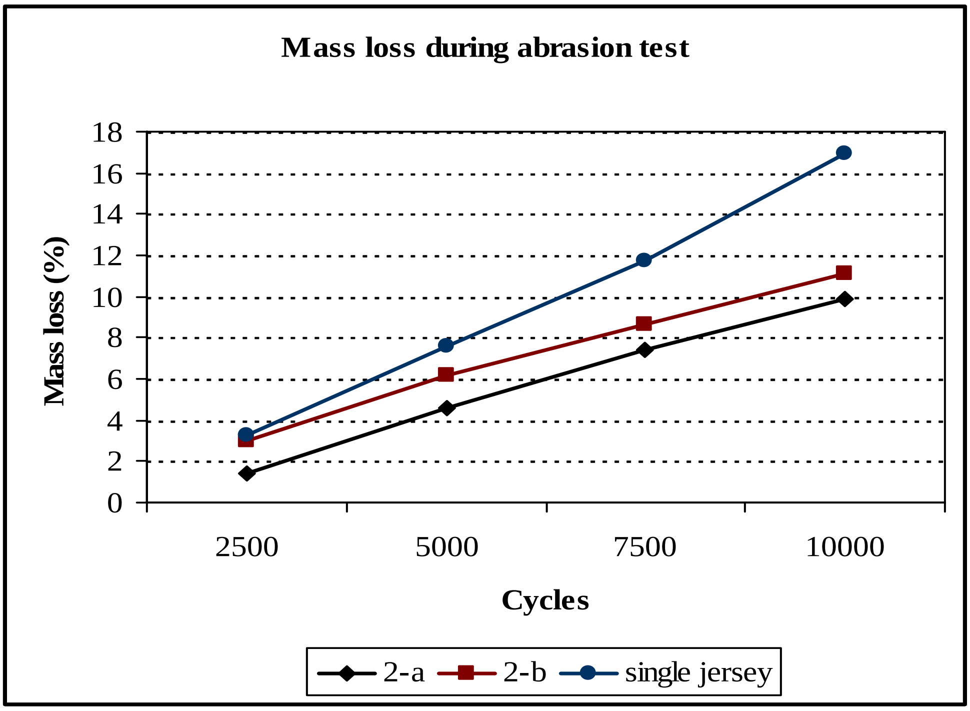


Figure C.2 Mass loss diagram for 2nd group gray samples

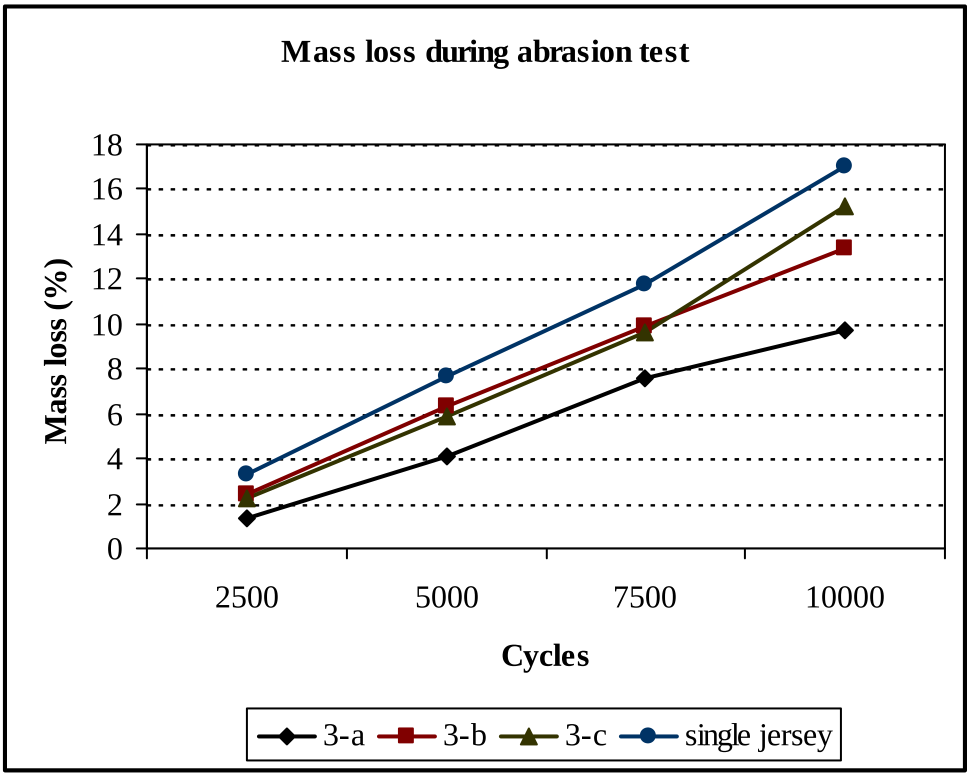


Figure C.3 Mass loss diagram for 3rd group gray samples

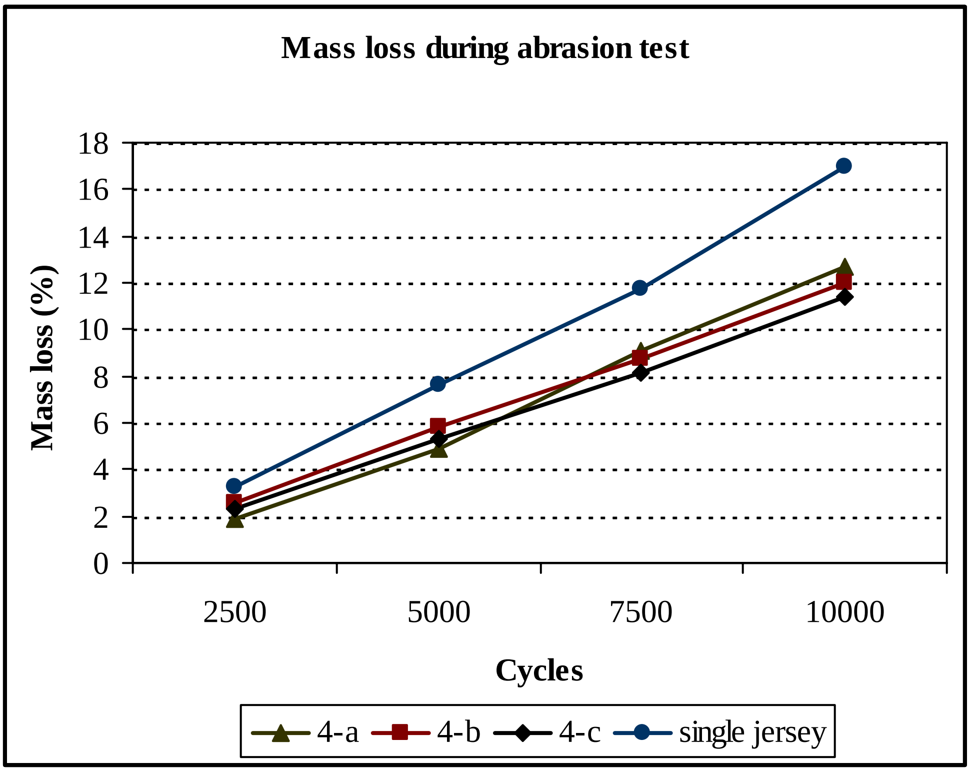


Figure C.4 Mass loss diagram for 4th group gray samples

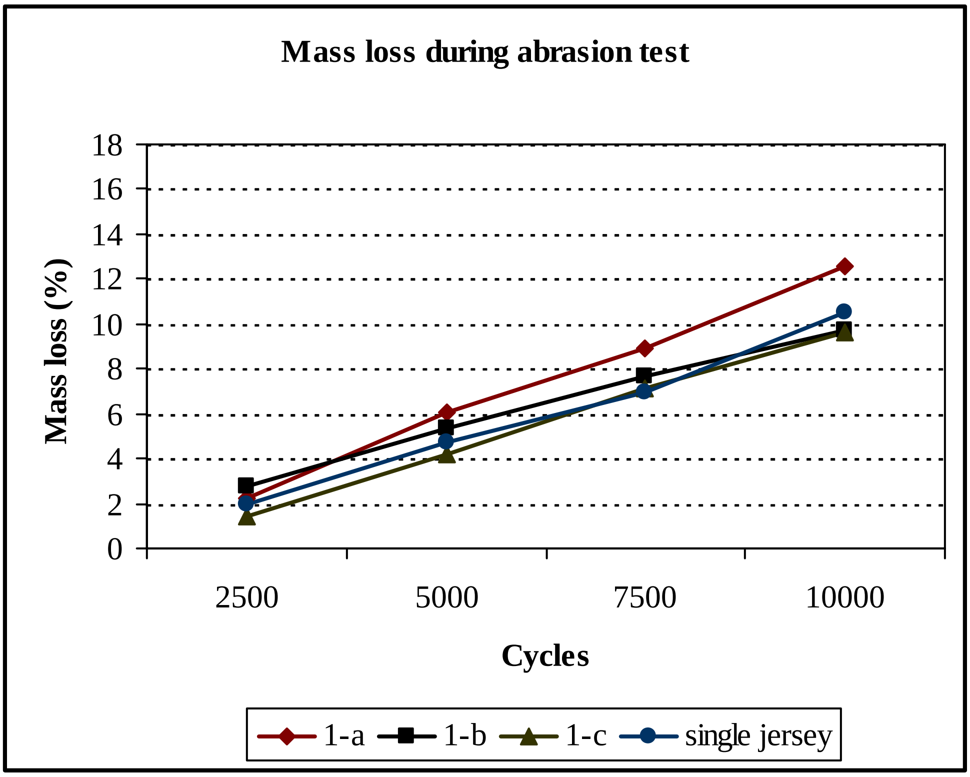


Figure C.5 Mass loss diagram for 1st group dyed samples

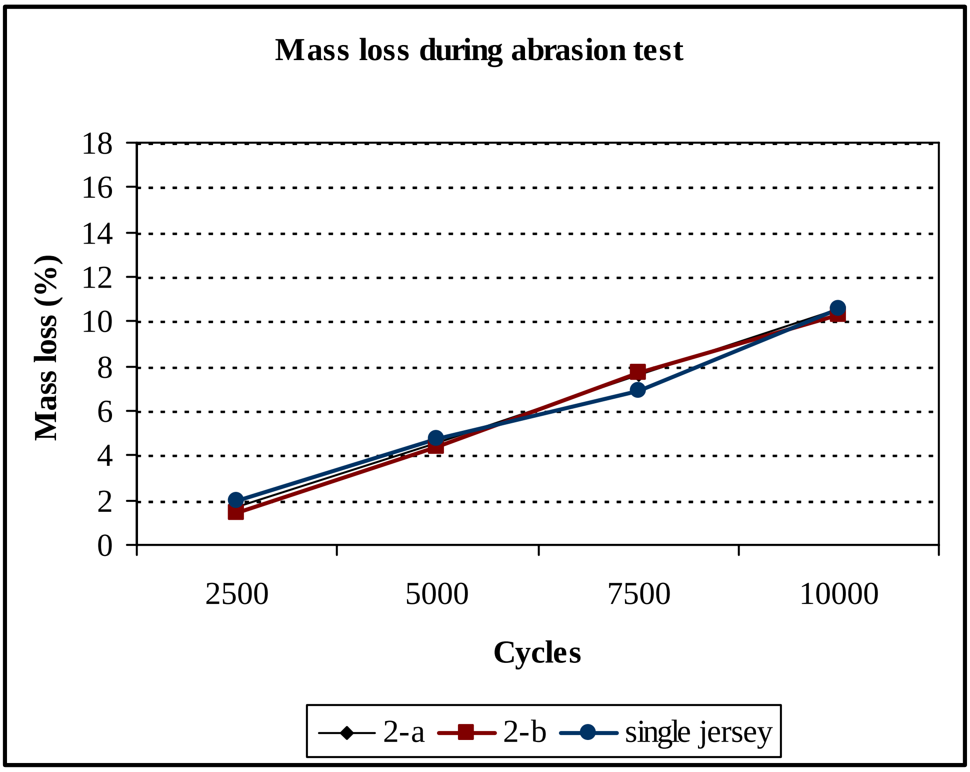


Figure C.6 Mass loss diagram for 2nd group dyed samples

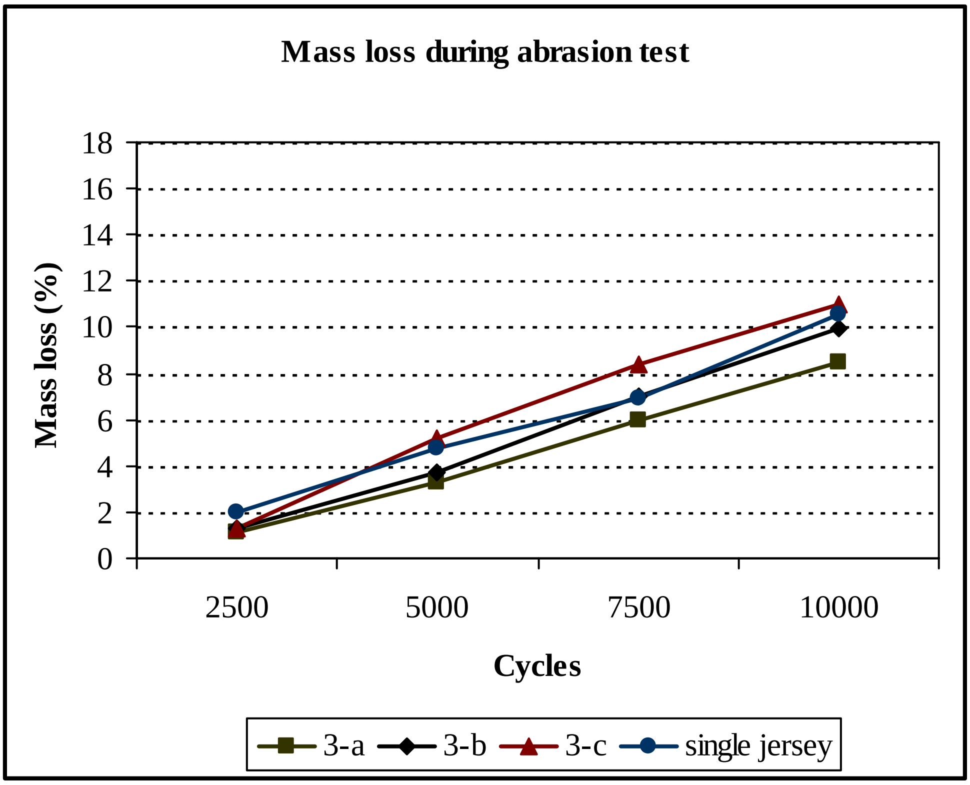


Figure C.7 Mass loss diagram for 3rd group dyed samples

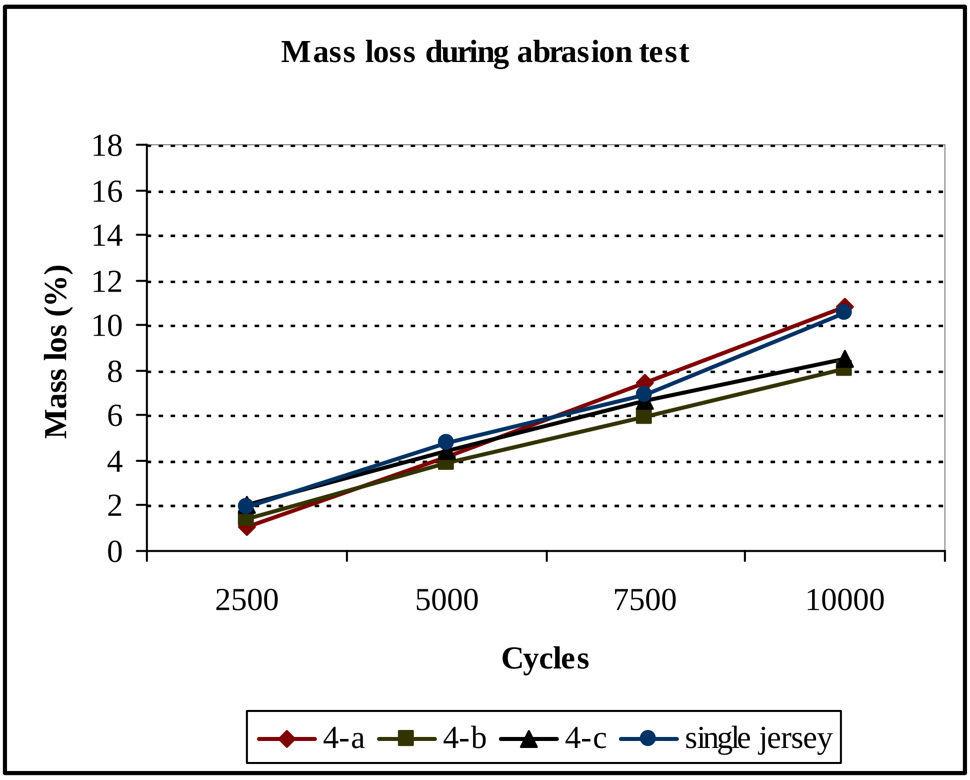


Figure C.8 Mass loss diagram for 4th group dyed samples

APPENDIX D

PILLING RESISTANCE DIAGRAMS FOR SAMPLES

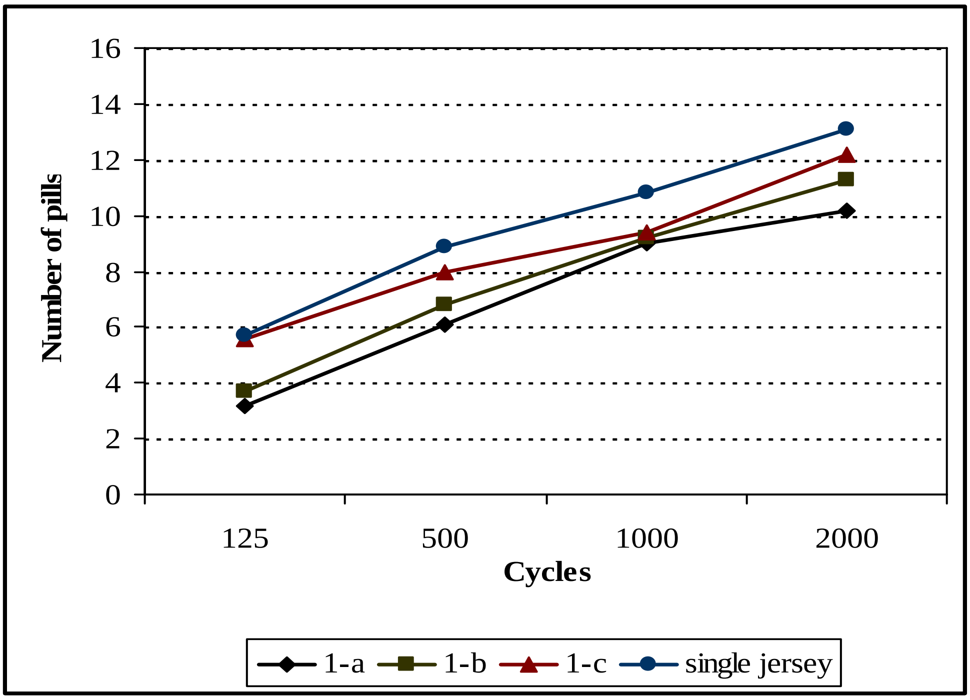


Figure D.1 Pill formation diagram for 1st group gray samples

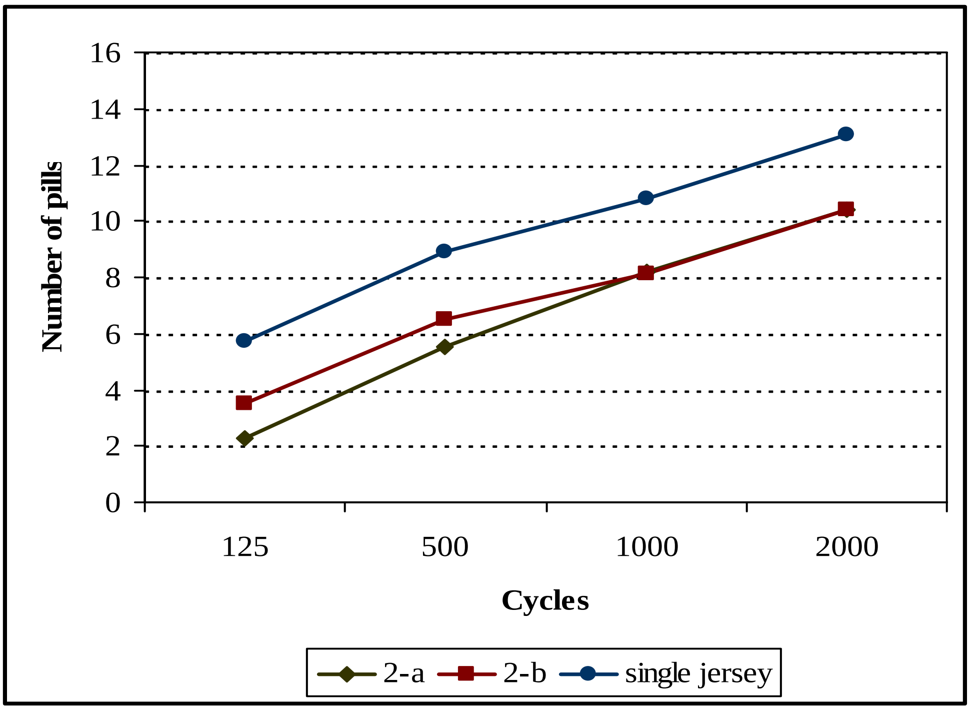


Figure D.2 Pill formation diagram for 2nd group gray samples

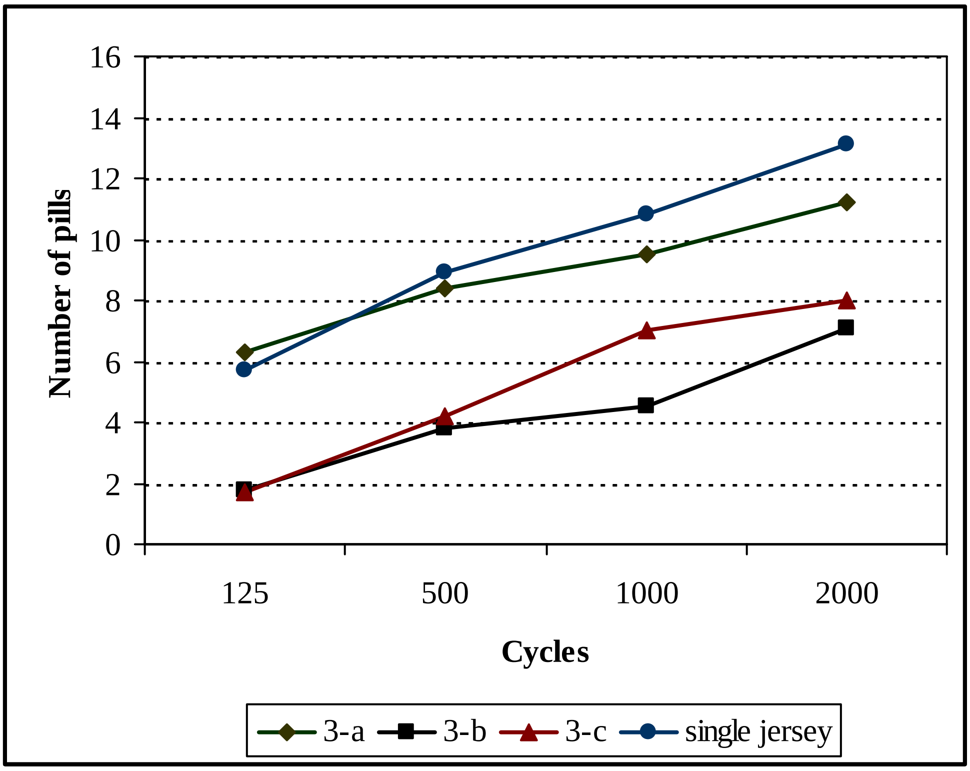


Figure D.3 Pill formation diagram for 3rd group gray samples

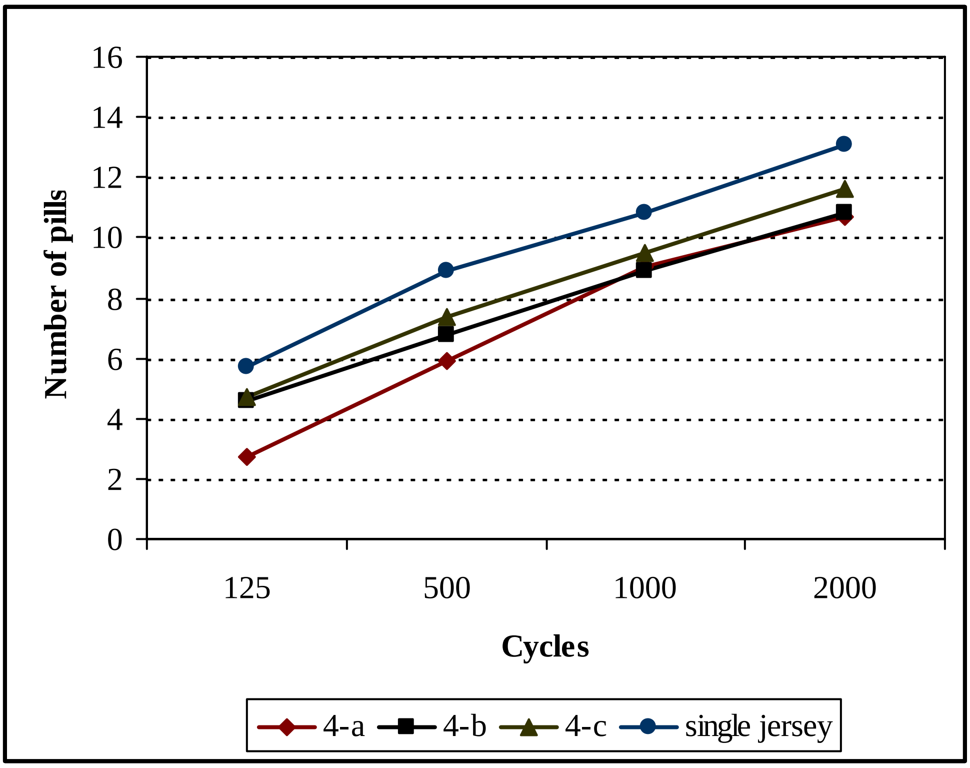


Figure D.4 Pill formation diagram for 4th group gray samples

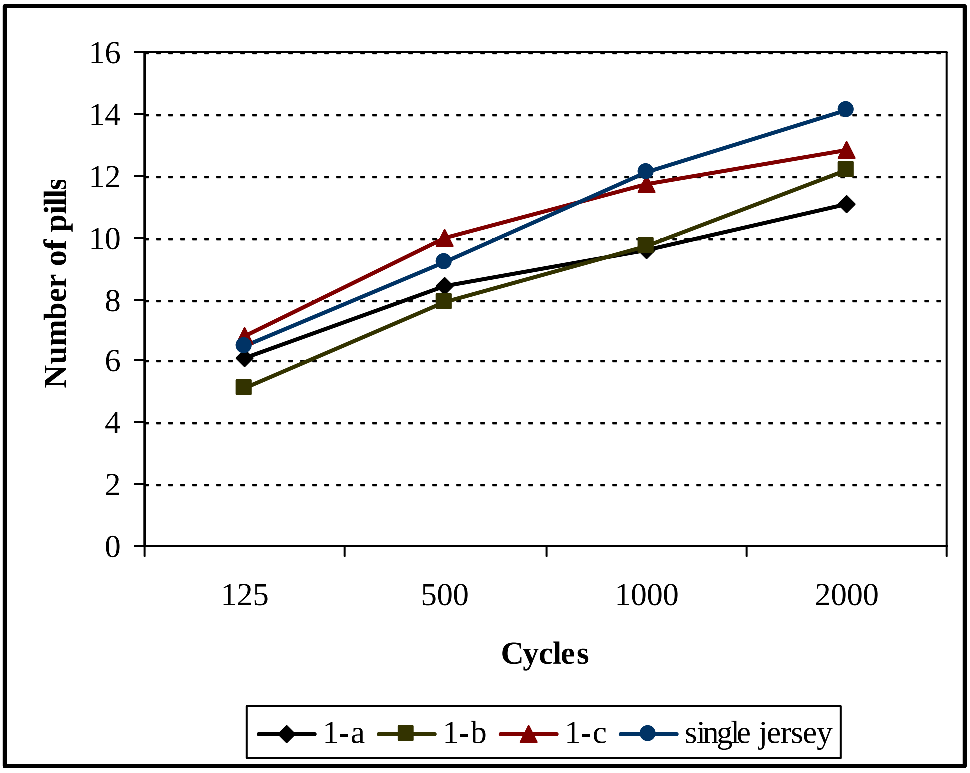


Figure D.5 Pill formation diagram for 1st group dyed samples

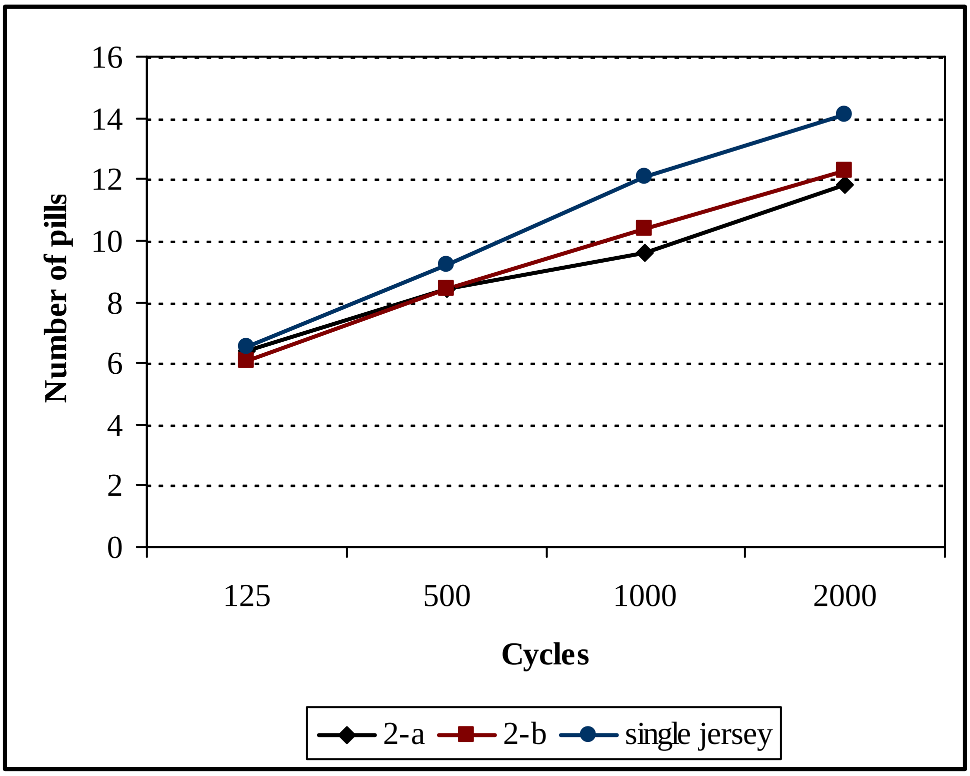


Figure D.6 Pill formation diagram for 2nd group dyed samples

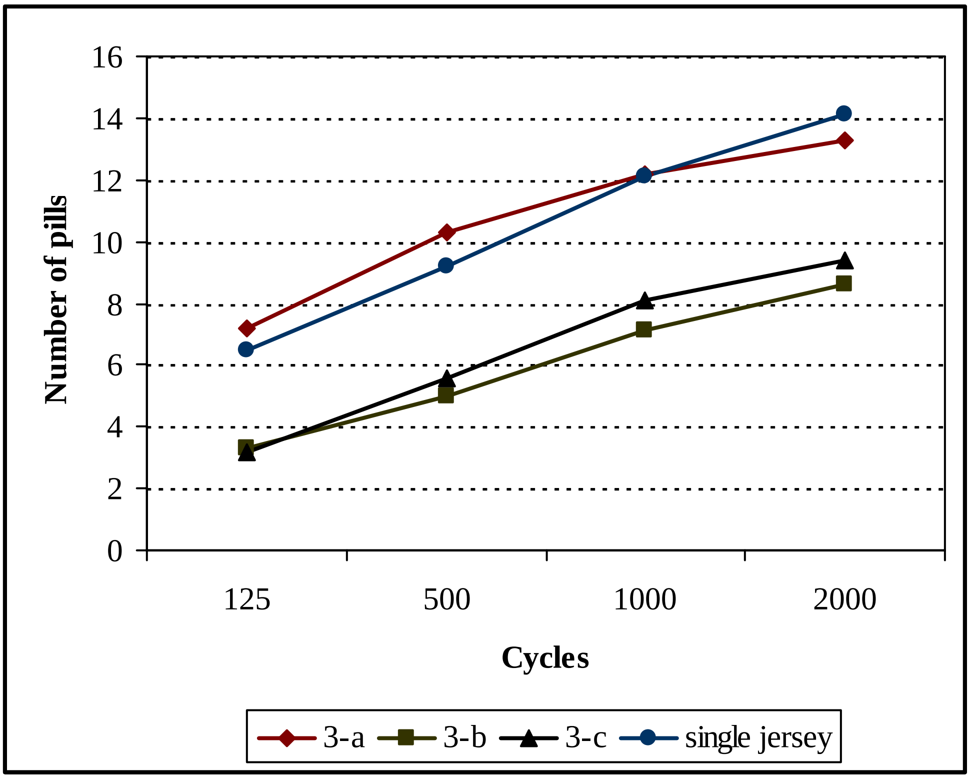


Figure D.7 Pill formation diagram for 3rd group dyed samples

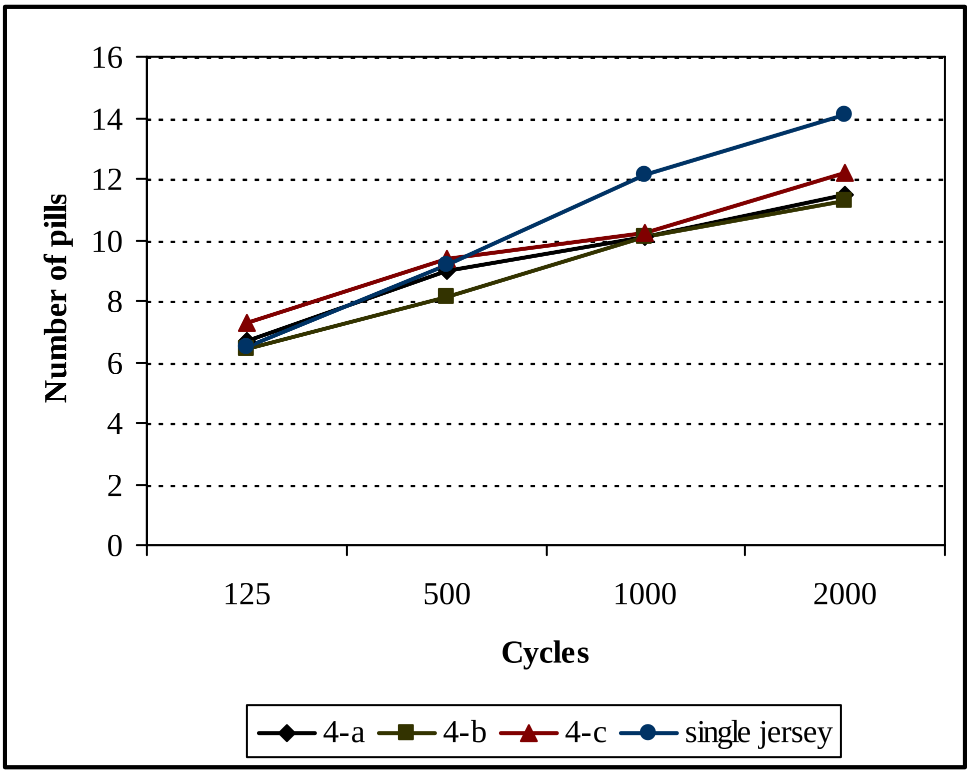


Figure D.8 Pill formation diagram for 4th group dyed samples

APPENDIX E

PHOTOGRAPHIC VIEWS OF SAMPLES

Figure E.1 Sample 1-a

Figure E.2 Sample 1-b

Figure E.3 Sample 2-a

Figure E.4 Sample 2-b


Figure E.5 Sample 3-a


Figure E.6 Sample 3-b


Figure E.7 Sample 3-c


Figure E.8 Sample 4-a


Figure E.9 Sample 4-b

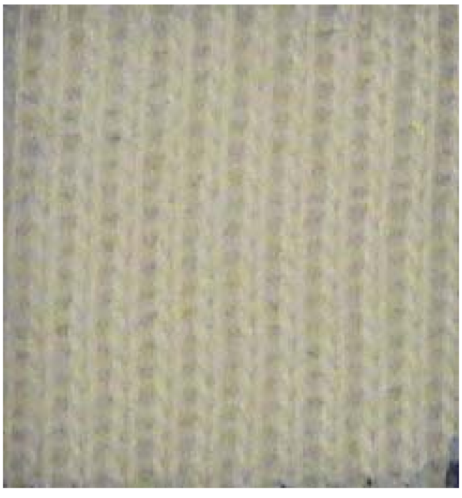


Figure E.10 Single jersey

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