THE EFFECT OF PARTICLE SIZE OF SILICONE TYPE OF SOFTENERS ON SEWING DAMAGE OF DENIM FABRICS

University of Gaziantep

M.Sc. Thesis

in

Textile Engineering

Supervisor

Assoc. Prof. Dr. Cem GÜNEŞOĞLU

Co - Supervisor
Instr. Dr. Sinem GÜNEŞOĞLU

By

Esin BABALIK

December, 2012

T.C.

UNIVERSITY OF GAZIANTEP

GRADUATE SCHOOL OF

NATURAL & APPLIED SCIENCES

TEXTILE ENGINEERING

Name of thesis : The Effect of Particle Size of Silicone Type of Softeners on Sewing Damage of Denim Fabrics

Name of student : Esin BABALIK

Exam date : 13/12/2012

Approval of the Graduate School of Natural and Applied Sciences

Assoc. Prof. Dr. Metin BEDİR
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science/Doctor of Philosopy.

Prof. Dr. Ali KİREÇCİ
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis fort the degree of Master of Sciene / Doctor of Philosophy.

Assoc. Prof. Dr. Cem GÜNEŞOĞLU
Supervisor

Instr. Dr. Sinem GÜNEŞOĞLU
Co - Supervisor

Examining Committee Members: Signature:

Prof. Dr. Ali KİREÇCİ ....

Assoc. Prof. Dr. Mehmet TOPALBEKİROĞLU ....

Assist. Prof. Dr. Mehmet ORHAN ....

Assist. Prof. Dr. Mehmet DAŞDEMİR ....

Assoc. Prof. Dr. Cem GÜNEŞOĞLU ....

I declare that the related thesis was written and all the relevant literature was used in accordance with the academic and ethical rules.

Esin BABALIK

ABSTRACT

THE EFFECT OF PARTICLE SIZE OF SILICONE TYPE OF SOFTENERS ON SEWING DAMAGE OF DENIM FABRICS

BABALIK, Esin

M.Sc. in Textile Engineering

Supervisor: Assoc. Prof. Dr. Cem GÜNEŞOĞLU

Co-Supervisor: Instr. Dr. Sinem GÜNEŞOĞLU

13/12/2012

57 Pages

To maintain the quality and the handle properties of apparel become so popular. One of the most popular fabric qualities in woven garment manufacturing is denim fabrics. For denim garment production quality sewing parameters are important. Besides, handle of denim garments fabrics is an important parameter. Also, seam damages are serious problems for apparel production and most of them caused by needle penetration forces. To reduce needle penetration force during sewing softening finishes are used. The main object of this study is to investigate the effect of the particle size of the silicone softeners on a certain sewing damage at denim fabrics.

Key words: Needle cutting index, needle size, silicone softeners, needle-related damage

ÖZ

SİLİKON YUMUŞATICILARIN PARÇACIK BÜYÜKLÜKLERİNİN DENİM KUMAŞLARIN DİKİMİ ÜZERİNE ETKİSİ

BABALIK, Esin

Yüksek Lisans Tezi, Tekstil Mühendisliği Bölümü

Tez Danışmanı: Doç. Dr. Cem GÜNEŞOĞLU

İkinci Tez Danışmanı: Öğr. Grv. Dr. Sinem GÜNEŞOĞLU

13/12/2012

57 Sayfa

Konfeksiyon ürünlerinin kalitesi ve tutum özelliklerinin korunması popüler hale gelmiştir. Dokuma kumaş hazır giyim üretiminde en çok kullanılan kumaş çeşidi denim kumaşlardır. Denim hazır giyim imalatında dikiş parametrelerinin kalitesi önemlidir. Bunun yanında denim ürünlerin tuşesi de önemli bir parametredir. Ayrıca, iğne batışından kaynaklı kuvvetlerin ortaya çıkardığı dikiş hasarları, hazır giyim üretiminde ciddi problemlerdir. Dikiş işlemi esnasında dikiş batışlarından kaynaklanan kuvvetleri azaltabilmek için silikon yumuşatıcılar kullanılmaktadır. Bu çalışmanın amacı parçacık büyüklüğü değiştirilmiş silikon yumuşatıcıların denim kumaşların dikiminde meydana gelen dikiş hasarına etkisini araştırmaktır.

Anahtar kelimeler: İğne kesme indeksi, silikon yumuşatıcılar, iğne numarası, iğne kaynaklı hasar

ACKNOWLEDGEMENTS

First of all, I express my sincere gratitude to my supervisor Assoc. Prof. Dr. Cem GÜNEŞOĞLU, for giving me continuous guidance and support during the entire project work. It has been really a great experience for me to work under his supervision.

I would like to thank to İnternet Tekstil A.Ş. Adıyaman, espcially, Production and Process Manager Hüseyin Eren for helping me in the experimental work, CHT Tekstil for providing the silicone softeners and GAP Tekstil for providing the denim fabrics.

Finally, big thanks from deep of my heart to my husband Kerem BABALIK for supporting and encourage me throughout this thesis.

CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES Page

Page

ABBREVIATIONS

SS	sum of squares
df	degree of freedom
ms	mean of squares
F	F statistic ratio
P	probability
SNK	Student-Newman-Keuls
ns	non-significant
OE	open end
PDMS	polydimethylsiloxane
UV	ultraviolet
IR	infrared
NCI	needle cutting index

CHAPTER 1

INTRODUCTION

1.1. Introduction

Denim fabric is the most popular fabric type in garment manufacturing. Denim, which is characterized with certain physical properties, is a generally cotton fabric produced for work and sportswear for years thanks to superior abrasion and tear resistance than other fabric types like gabardine and poplin. Denim fabric is used to produce trouser, jacket, shirt, working cloths and bags etc. Its production and the consumption have increased day by day. For denim apparel production quality, choosing the suitable sewing parameter is so important. As a function of the fabric construction, yarn construction, tightness of the denim fabric, during sewing process, needle damages can be occurred because of the needle penetration force. Seam damages are serious problem for apparel production costing and often showing after the garment has been worn. Seam damage is unacceptable in any apparel because it results in reducing in seam strength, poor appearance, or both, due to frayed yarns.

The quality and performance of a sewn garment depends on various factors such as seam strength, seam slippage and seam puckering and appearance. Those factors may be contributed to the seam damage tendency of fabrics where fabric construction, chemical treatments, sewing needle size (thickness), sewing thread and sewing machine settings have also important influence. Generally, in the seam operation, finishing with silicone reduces the friction between the fabric and the needle. Consequently, the needle penetration force and damage to the fabric is also decreased [15]. The silicone finish reduces the friction between fabric yarns by increasing their mobility.

The silicone softeners are most important and most used finishing auxiliaries in textile. Silicone softeners provide their main effects on the surface of the fibers. They have affect on tear resistance, abrasion resistance and fabric sewability.

1.2. Objective of Study

The main objective of this study is to investigate the effect of the particle size of silicone softeners on a certain sewing damage (needle cutting index) at denim fabrics. Silicone softeners are important finishing auxiliaries in textile because of their impact on quality and sewing performance. The silicone emulsions are available in various particle sizes – macro (milky, particle size – 150-300 nm.), semi micro (hazy, particle size – 80-120 nm) or micro (Transparent, particle size below 40nm) forms [8]. The macro, semi micro and micro particle size of silicones are selected for this study with three different needle sizes to evaluate the needle cutting index.

There are various papers on the similar topic however they have been conducted on knitted fabrics or common woven types like gabardine and poplin. In the paper prepared by Nayak, Padhye and Gon (2010) an attempt has been made to investigate the effect of lycra percentage, type of sewing thread and silicone finish on sewability of denim fabrics. Hurt and Tyler worked on the needle penetration force measurement in 1975 & 1976. Regarding fabric finishing some researchers have found that the softeners affect the needle penetration forces. Besides, in recent work, Gurarda and Meric (2005) conclude that the finishing processes have effects on the seam performance, needle penetration forces during the sewing.

This study is subjected to denim fabrics to evaluate the effect of softener type on sewing damage of denim samples and best to our knowledge there is not sufficient data in literature on this topic.

1.3. Structure of the Thesis

Textile finishing processes are for improving the appearance, texture and the performance of the textile materials by the way of chemical, mechanical and thermal. The general definition of the finishing and its importance in textile is given in Chapter 2. Beside, the softening finishing process is explained in detailed form.

In Chapter 3, the chemical softening mechanism is explained and the softening auxiliary types are given. Also the silicone softener types are examined in detailed.

Chapter 4 includes denim fabric manufacturing steps from yarn production to weaving operation. Additionally dyeing of the denim fabric is explained.

Chapter 5 includes the description and the evaluation of the sewing quality. One of the evaluation parameter of the sewing quality is needle damages. For the determination of the sewing damage, needle cutting index is used. Calculation of the needle cutting index and sewing needle size effect are given in this chapter.

In chapter 6, the materials and experimental are presented. Used fabric parameters, silicone treatment processes, fabric specimen preparation explained in detailed form.

Chapter 7 covers results and discussion. Costat was used for all statistical procedures. The results of needle cutting index values were evaluated by analysis of variance and performing Student Newman Keuls. The conclusion of this study is given and recommendation for further studies is presented.

CHAPTER 2
SOFTENING FINISHES

Textile finishing consists of mechanical, thermal and chemical processes that improve the appearance, texture or performance of a textile material.

Softening finishing applications could considerably change the appearance and properties of textile materials. Because of that reason softening applications are so popular in textile finishing.

The operations carried out in a textile finishing mill include:

(1) Preparation of fabric including scouring and bleaching for to make the fabric ready for finishing processes;

(2) Coloring (which is consist of dyeing and printing);

(3) Mechanical finishing procedures which are usually treated on dry textile material;

(4) Thermal processes for drying, fixing and heat setting;

(5)Wet finishing processes in which the fabrics are treated with solutions of appropriate chemicals and afterward dried. [5]

2.1. Mechanical Finishing

It has been known that woven, knitted and non-woven fabrics need to modify their appearance and handle. The physical or mechanical treatments could considerably change the appearance and the handle of those materials. Mechanical finishing processes can provide the properties of the fabrics. They can produce different effects on fabric, such as calendaring, raising…etc. These processes obtain to produced a fabric with a special feel or handle more dense and shiny appearance. [18]

Mechanical finishing produces a variety of different effects. Mechanical finishing processes and their objectives are given in Table 2.1. These processes are used on a variety of fabrics containing different types of fibers. The use of calendars to flatten or compact or to produce polished fabrics is important. Calendaring is the compressing of the fabric between cylinders under the effect of the pressure and heat.

After this treatment the fabric gains a flat and smooth fabric surface. The brushing or raising of suitable substrates to produce pile fabrics is demanded by fashion trade. Raising or napping is an old mechanical finishing technique. This finishing is suitable for wool and cotton fabrics. With using sharp steel points the fiber ends lifted and pulled to the fabric surface. By means of this process a fuzzy surface can be given to the fabric. Raising modify the fabric appearance and provide softer and fuller hand. For the complementary to the raising process, shearing operation is used. Shearing is a cutting operation which determines the height of the fibers. After this cutting operation fabric appearance and handling becomes smoother like velvet. Compressive shrinking of cotton fabrics avoids shrinkage when a fabric is wetted. Heat setting of materials made from thermoplastic synthetic fibers stabilizes their shape and dimensions. [4, 18]

Table 2.1: Mechanical finishing processes and their objectives

PROCESS	**OBJECTIVE**
Calendering	Pressing and smoothing the surface of the fabric
Napping or Raising	Breaking fibers in the yarn surface an raising a pile
Brushing	Laying the pile in the same length
Shearing	Cutting the pile fibers all to the same length
Compressive Shrinking	Compressing the fabric to the dimensions it would have after shrinkage caused by washing

The main effect of these processes is to modify the fabric surface, to make the handling of fabric smoother, or to raise a pile. Both effects can cause a change in the perceived color of the material because they modify the reflection of light from the fabric surface [5, 17]

2.2 Chemical Finishing

Chemical finishing gives fabrics some properties and allows the stabilization of fabrics that subjected to mechanical finishing processes. Generally, chemical finishing processes are applied to the fabrics that containing cellulosic fibers. There are a large number of chemical treatments for fabrics that impart specific properties such as water repellence, softness of handle, flame resistance, easy soil release or anti-bacteria. [4, 5]

Textile auxiliaries are used in finishing, the largest percentage usage of all textile chemicals. Thousands of formulated textile auxiliaries are produced world-wide to provide process ability of fibers as well as desired quality of the final textile goods. Within the textile finishing group the product breakdown is given on Table 2.2. All fibers, whether natural or synthetic based, need to obtain a certain finish such as soft handle, smoothness or bulkiness, as well as hydrophicity. Softeners are defined as "an auxiliary" that improves the handle of the fabric when applied on. This specialty makes them clearly the most important individual product group. Softeners are clearly the most important individual finishing product group and now produced for all types of fibers from a wide range of chemicals. [2, 35]

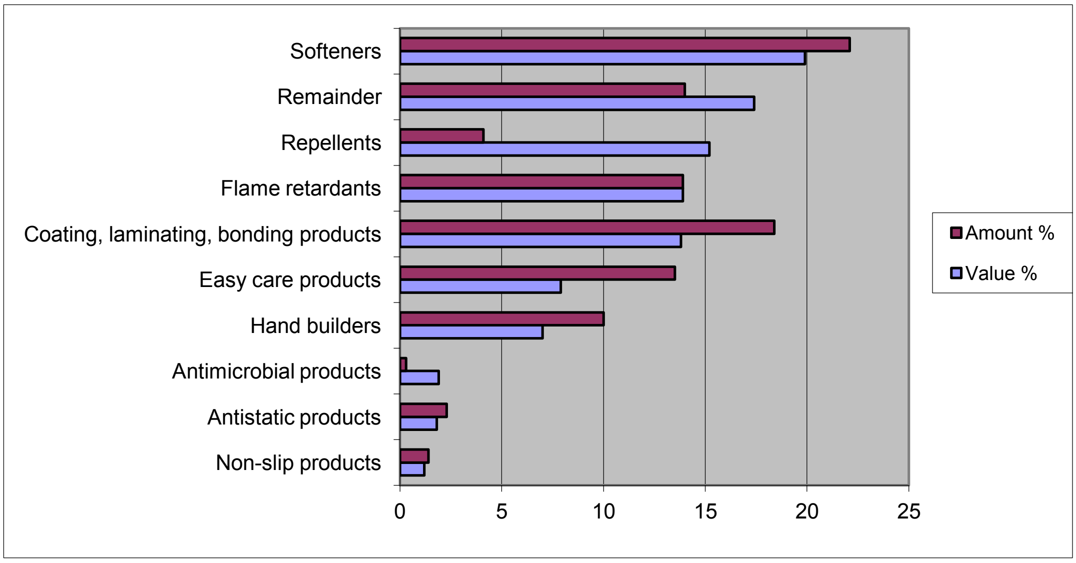

Figure 2.1: Distribution of finishing product groups by amount and value [35]

2.2.2. **Silicone finishes**

Silicone finishes for textiles offer durable soft finish to cotton and its blended fabrics apart from offering aesthetic features. Silicones are widely used as fabric softening agent. They lubricate the fibers and give a soft handling to fabric. Silicones are used as antistatic agents, fiber and thread lubricants during fabric production and antifoaming and fabric softening agents during the fabric finishing. Actual and potential contributions of silicones to today's garment needs can be grouped in three categories.

- Garment comfort including benefits such as fabric elasticity, softness, breathability, static-free properties, water absorbency and perfume release characteristics.
- Garment protection including benefits such as water resistance, wind proofing, abrasion resistance and antimicrobial properties.
- Easy care including benefits such as wrinkle resistance, ease of ironing, fabric dewatering, shrinkage control, durable press, finish durability, strength retention and soil release compatibility. [16]

The performance of a silicone finish varies depending upon the functionality and molecular weight of the silicone polymer. The chemistry of silicones for textile treatment is big and the commonly used silicones in textiles have amino, amido, organo and epoxy functionalities. Depending upon the functionality in the polymer chain, they offer a wide range of performance properties like durable softness, sewability, lubricity, elasticity, hydrophobicity, hydrophilicity, wrinkle and stretch recovery. [22]

Silicones are polysiloxane polymers which are with backbones that consist of alternating oxygen and silicon atoms. The silicon-oxygen bonds are strong and very flexible compared to the carbon-carbon bonds found in the backbones of other polymers. One of the simplest silicone examples is poly (dimethyl siloxane) (PDMS), in which the remaining bonding sites on the silicon atom are taken by methyl groups. The chemical structure of a silicone polymer or polydimethylsiloxane (PDMS) is characterized by an inorganic Si – O backbone on which side groups are attached. (See Figure 2.1) [7, 16]

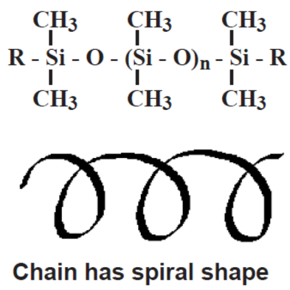

Figure 2.2: Molecular structure of polydimethylsiloxane (PDMS) R =OH or CH_3

The first silicone applications on textile have developed in 1950s, where low viscosity silicones were used as water repellents. The high viscosity silicones used for softness. Because of their economical problems emulsion polymerization has developed in 1960s. The silicones used in textile finishing are partially polymerised methylsilanols in an organic solvent or aqueous dispersion (Figure 2.1). As mentioned before, they contain an organometallic catalyst. This organo metallic part used to promote polymerisation on the fiber surface. The orientation of the polysiloxane molecule on the fiber surface provides the water repellency. The polar oxygen atoms along the silicone chain are oriented towards the polar fiber and the methyl groups away from it. This is assisted by the incorporation of zirconium or titanium compounds. In this way, the surface of the fibers presents an array of hydrophobic methyl groups that provide soft handling. [2, 5, 18]

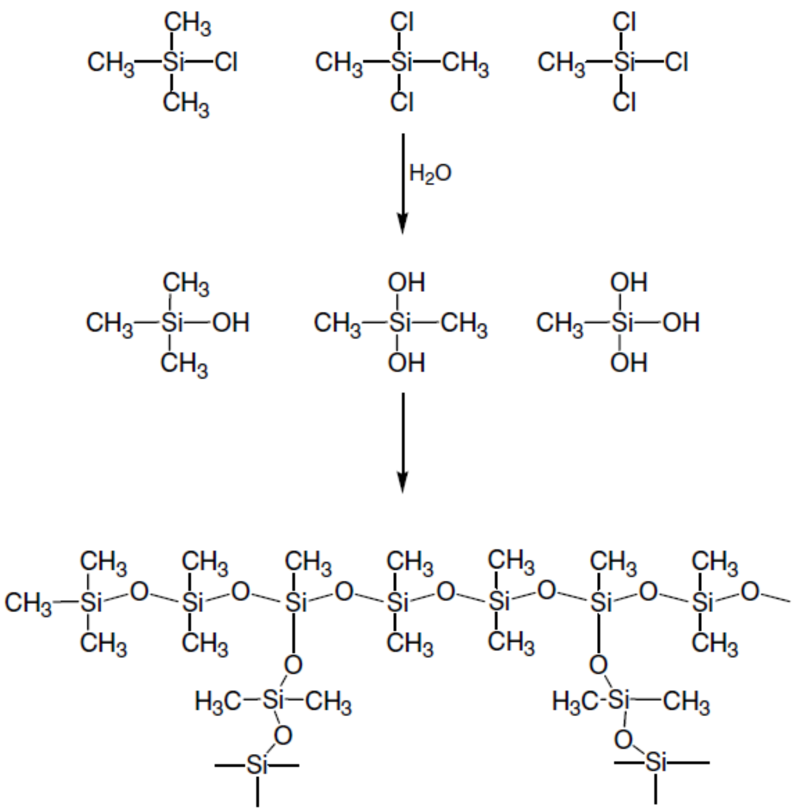

Figure 2.3: Polymerisation of methylsilanols

Because of the low durability of the PDMS to drying and laundering the reactive polysiloxanes were developed to produce more permanent finishes. Reactive silicone finishes that undergo more extensive polycondensation to a crosslinked polymer are more durable. One type of reactive polysiloxane has methylhydrogensiloxane units as shown in Figure 2.2. The reactive silicon–hydrogen bond reacts with water to produce hydrogen and a silanol group that then undergoes further polycondensation resulting in chain crosslinking. These reactive silicones provide a good permanency at silicone finishing and are important additives to permanent press finishing formulas waterproof finishes, machine wash treatments. Besides, the permanency on cotton fabrics during laundry can be satisfactory. [18]

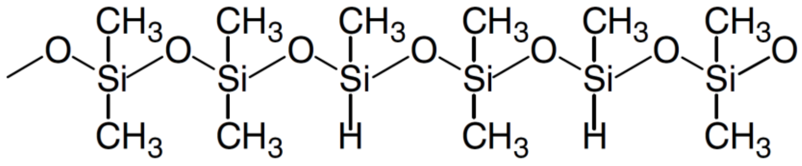

Figure 2.4**:** Reactive polysiloxanes [3]

Another type of reactive silicone finish depends on crosslinking a polysiloxane by means of reaction with methylsilanetriol generated by hydrolysis of its methyl ether. This type of crosslink is longer than those formed by condensation of hydroxyl groups in a polysiloxane. Polysiloxanes with short crosslinks are used mainly for water-repellent finishes. The more elastic types, with longer methylsilanetriol generated crosslinks, are softeners. In addition, a range of polysiloxanes with other functional groups is now available (Figure 2.3). These include polysiloxanes with amino or epoxy groups, the numbers of such groups depending upon the particular effect required. They are excellent durable softening agents. The epoxy functional silicones comprise an important subset in the reactive polymethilsiloxane range. Epoxy silicones improve dimensional stability and are better softeners than PDMS. They have durability to domestic laundering and have low yellowing properties. [5, 18]

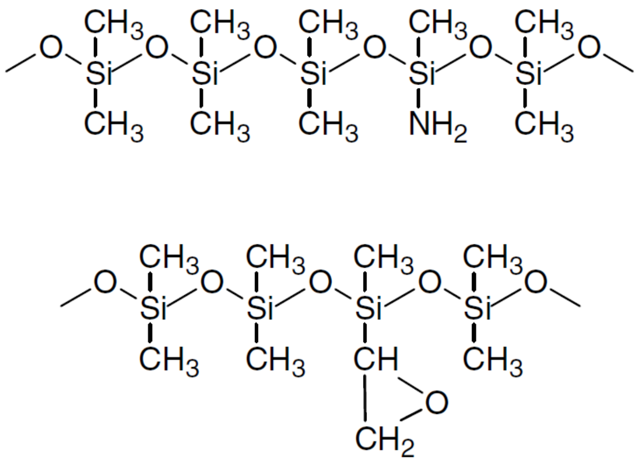

Figure 2.5: Functionalised polysiloxanes

CHAPTER 3
CHEMICAL SOFTENING OF FABRIC

The use of soft finishes is universal. Chemical softening finishes have an important place in textile chemical treatments. Using with chemical softeners, textiles can reach an agreeable, soft hand (supple, pliant, sleek and fluffy), some smoothness, more flexibility and better drape and pliability. The feel of a textile material is determined by the fabric construction and the fineness fibers which consist of. The processing of textiles to achieve a particular 'handle' or softness is one of the most important aspects of finishing technology. [6] Most mechanical finishing treatments improve fabric handle, but the treatment with a chemical softening agent regenerates the softness and drape of fabrics. [19]

Comfort is the most important request that comes from the final consumers. Because of that reason good production processes has achieved and production was resulted with better handle on fabrics. It is obvious that the fabric properties depend on fabric construction, fineness of fibers and finishing treatments. For improving the fabric properties some chemical and most mechanical processes applied on. [13]

The hand of fabric is subjective sensation felt by the skin when a textile fabric is touched with the finger tips and gently compressed. The perceived softness of a textile is the combination of several measureable physical phenomena such as elasticity, compressibility and smoothness. Preparation processes for fabrics makes textiles embrittled, because natural oils and waxes or fiber preparations are removed. Finishing with softeners can beat this deficiency and even improve on the original softness other properties and sewability. Using chemical softeners can expose some disadvantages, such as, reducing crock fastness, yellowing of white goods, changes in hue of dyed goods and fabric structure slippage.

The feel of a fabric and the measurement of softness or handle is a subjective sensation felt by the skin when a textile fabric is touched with the finger tips and gently compressed. The perceived softness of a textile is determined by the fabric construction, and the fineness of its fiber consumption.

For softening impression, the treatments which make the fabric more flexible and elastic impart are used. Softness generally comes from making the fibers themselves more flexible and from decreasing friction between the fibers. [11, 35]

As generally, each fiber has its specific softness value, which depends on its chemical composition and physical structure. The smoothness of the fabric depends on the chemical structure of the fiber that consist of. There is an inverse ratio between the fiber crystallinty and the softness (less crystallinity = greater softness). The fineness of the fiber affects the softness of the yarn (woollens, worsteds, microfibers etc.). The construction of the yarn, such as yarn twist ratio, affects the softness of the fabric in a conversely ratio. Also the weave of the fabric contributes to reducing (closer weave = cloth) or increasing (looser weave = satin) the fabric softness. In weaving structure, the number of yarns per centimeter can increase the stiffness of the fabric. [4]

Softeners are chemicals that alters the fabric hand and these softening effect can be carried out by the improving the softness characteristics of the fabric. The softness characteristic of the fabric is depended on the composition and the construction of the fabric. The softness can be classified into 3 groups:

1. Surface softness
2. Surface smoothness
3. Elasticity

The softened fabric is fluffier and has better drape. Drape is the ability of a fabric to follow the contours of an object. In addition to aesthetics (drape and silkiness), softeners improve abrasion resistance, increase tearing strength, reduce sewing thread breakage and reduce needle cutting when the garment is sewn. [4, 38]

We can apply mechanical, physical and chemical or combination of the finishing techniques to change the hand properties of a textile fabric. On the other hand, we can obtain the best softening effect by carrying out the physical-mechanical processes and applying a special chemical softening agent.

3.1. Softening effect mechanism

The basic function of a softener is to impart a particular handle to textile surface. This may be required to overcome the naturally harsh feel of the fabric or to disguise harshness imparted by chemical processing of the fabric. The performance of a softener will be altered by the nature of the fabric to which it is applied. [6]

Softening of textile fabrics is reducing the coefficient of the friction between the fibers, filaments and yarns. Softeners provide their main effects on the surface of the fibers. Small softener molecules, in addition, penetrate the fiber and provide an internal plasticization of the fiber forming polymer by reducing of the glass transition temperature T_g. The physical arrangement of the usual softener molecules on the fiber surface is important and shown in Figure 3.1. Cationic softeners orient themselves with their positively charged ends toward the partially negatively charged fiber (zeta potential), creating a new surface of hydrophobic carbon chains that provide the characteristic excellent softening and lubricity seen with cationic softeners. Anionic softeners, on the other hand, orient themselves with their negatively charged ends repelled away from the negatively charged fiber surface. This leads to higher hydrophobicity, but less softening than with cationic softeners. The orientation of non-ionic softeners depends on the nature of the fiber surface, with the hydrophilic portion of the softener being attracted to hydrophilic surfaces and the hydrophobic portion being attracted to hydrophobic surfaces. [35]

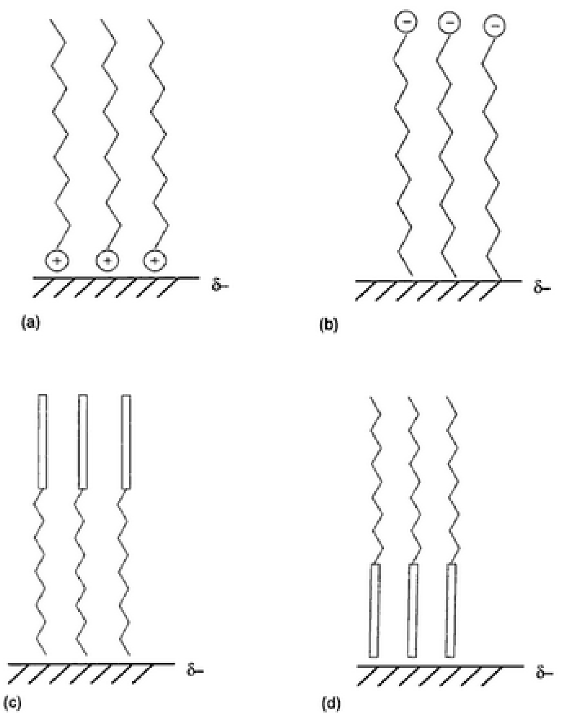

Figure 3.1: a. Cationic softener at fabric surface
b. Anionic softener at fabric surface
c. Nonionic softener at hydrophobic surface
d. Nonionic softener at hydrophilic surface

3.2. Softeners and softener chemistry

Softeners contain one or two long, hydrophobic chains, usually C_{18} hydrocarbon.[18] Softeners are surface active agents with long chain hydrophobic and short hydrophilic polar water soluble “head” group. The softener molecules typically contain a long alkyl group (hydrophobic chain), sometimes branched, of more than 16-22 carbon atoms, but most have 18 corresponding to the stearyl residue (remarked as $C_{18}H_{37}$). Exceptions to these structures, there are special categories of silicones, paraffin and polyethylene softeners. [11]

Table 3.1: Classification of finishes by ionic nature [18]

Product type	***Electrical charge***	***Characteristics***
Cationic	*Positive (+)*	*Best softeners*
Pseudo ionic	*Mostly positive (+/0/-)*	*Lubricative finishes*
Amphoteric	*Varies with pH (+/-)*	*Surfactant compatible*
Non-ionic	*Neutral (0)*	*Best compatibility*
Anionic	*Negative (-)*	*Special properties*

3.2.1. Cationic softeners

Cationic softeners are often used in domestic and industrial area. Home and laundry usage of cationic softeners is mainly in rinse conditioners. Industrial products of the cationics can be used with other textile chemicals in multifunctional formulations. There are several reasons for the importance of the cationics. [18]

- Cationics are effective softening agents and allowing a high degree of softening effect.
- Their substantivity against to fiber is good for all types of fibers, including glass fiber.
- The manufacturing technology is well established and their prices are economic for production.
- They provide bulky, full soft hand and well handle.
- They allow antistatic and lubricative properties to fibers.

Cationic softeners are ionic molecules that have a positive charge on the large part of the molecule. They have the best softness and are reasonably durable to laundering.

They attract soil, may cause yellowing upon exposure to high temperatures and may affect the light fastness of direct and reactive dyes. They may reduce water absorbency and wettability of fabrics.

An important quality of cationic softeners is that they exhaust from water onto all fibers. When in water, fibers develop a negative surface charge, setting up an electronic field for attracting positively charged species. These forces causes the cationic softener to deposit in an oriented fashion, the positive end of the softener molecule is attracted to the fiber surface forcing the hydrocarbon tail to orient outward. The fiber now takes on low energy, nonpolar characteristics; therefore, the fiber has the lowest possible coefficient of friction. Cationics are highly efficient softeners. The ionic attraction causes complete exhaustion from baths and the orientation on the fiber surfaces allows a monolayer to-be as effective as having more lubricant piled on-top. [11, 38]

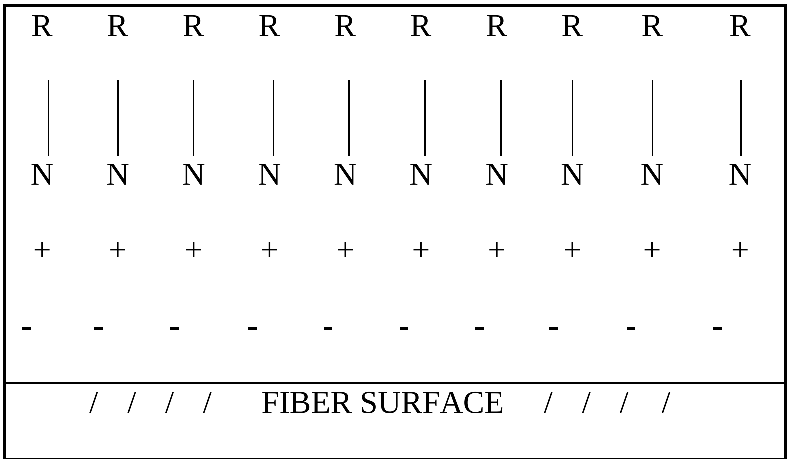

Figure 3.2: Adsorption on fiber surface

3.2.2. Anionic softeners

Anionic softeners were the first soft finishes to be used commercially. Anionic softeners are heat stable and provide strong antistatic effects and good rewetting properties. They provide good lubrication and improve the performance of fabrics in napping and raising. They are good foaming agents and mostly do not yellow. They have limited durability to laundering and dry cleaning. Anionic softeners have specialized areas of application, such as medical textiles. [11, 18]

3.2.3. Amphoteric softeners

Amphoteric softeners have medium softening effect. Their typical properties low permanence to washing and high anti-static effect. Amphoteric soft finishes have limited use in textile applications. They have found an application area on personal care production because of their low toxicity. Amphoteric softeners are surfactants that contain potentially anionic and cationic groups within the same molecule. [11, 18]

3.2.4. Non-ionic softeners

Non-ionic softeners can be divided into three subcategories, ethylene oxide derivatives, silicones, and hydrocarbon waxes based on paraffin or polyethylene, mostly based on paraffin and polyethylene are more stable products. They show high lubricity that is not durable to dry cleaning; they are stable to extreme pH conditions, and heat at normal textile process conditions. They are compatible with most textile chemicals. The industrial applications, non-ionic softeners probably dominate in terms of tonnage. They are not only wide used finishes in their own right by are also found as softeners, emulsifiers, stabilizers, extenders and lubricants. The most common application method of the non-ionic softeners is padding technique. The characteristics of the non-ionic softeners are:

- Compatibility: Selected compounds are tolerated to strong acid, alkalis and electrolytes found in easy-care and other finishes.
- Handle: Good control of handle and drape but cannot reach the softening effect with the cationic softeners.
- Lubricity: With the appropriate finishing application the smoothness control should be in widespread.
- Low yellowing effect: During the application in high temperature the operation will be end without yellowing. [11, 18, 38]

3.2.5. Ethoxylated non-ionic softeners

Ethoxylated non-ionic softeners are used extensively in softener formulations. They are polyglycol ethers, synthesized by the addition of ethylene oxide to general softener composition (i.e. fatty acids, esters or amides). They are surfactants and often used as antistatic agent or spin-finish agent. They have high substantivity, hydrophilcity, non-yellowing but low-softness effect. Ethoxylation improves product handling properties such as compatibility with pad bath additives and increases the hydrophilicity of the finish. [18, 38]

3.2.6. Silicone softeners

Probably the most widely used softener types in recent years are the silicones. Silicone softeners are becoming extremely important because of their very good softness and high wash durability compared to other softeners. A large amount of silicones is used in textiles as softeners. Silicone softeners are special softeners which can provide high softness, special hand, high lubricity, good sewability, elastic resilience, crease recovery, abrasion resistance and tear strength. They show good temperature stability and durability. They are common on white fabrics and are good sewing lubricants. The use of silicones in textile finishing has grown.

Three varieties of silicone polymers have found use as textile softeners. One of them is based on emulsified dimethyl fluids. They can improve the comfort and reduce the hydrophobicity. Another one is based on emulsified reactive fluids having Si-H groups dispersed throughout the polymer. This silicone groups provide a good permanent soft finish to many types of fabric. And the third one has amino or epoxy functional groups located on the polymer backbone. The epoxy silicones enhance dimensional stability. The amino and epoxy functional silicones have been reported to produce the softest possible hand and to improve the durable press performance of cotton fabrics. [18, 38]

An overview of the generic properties of the different chemical softeners types is given in Table 3.2.

Table 3.2: Important softener characteristics [11]

Chemical Type	Softness	Lubricity	Hydrophilicity	Substantivity	Stability to yellowing	Non-foaming
Anionic	+	++	++	-	++	-
Cationic	+++	-	--	+++	-	+
Amphoteric	++	-	+++	+	-	-
Non-ionic	+	++	++	++	+	-
Polyethylene	+	+++	-	-	+	++
Silicones	+++	+++	- to +	+++	+++ to +	++

Silicones used for textile treatment because of their desirable properties which are listed below:

- Silicones have highly flexible backbones. Because of the free rotation of the Si-O bonds the films are flexible and lubricate.
- They have very low surface tension which reduces the fiber to fiber cohesion, maximizing the fabric bulk and water repellency.
- Low glass transition temperature
- Because of the low vapor pressure of the silicones the weight loss on heating will be less.
- Silicones are resistant to strong oxidative attack and only show weakness under strong alkaline conditions at high temperature. They are resistant to UV and IR radiation.
- They have permeability to oxygen and this specialty provides wearing comfort.
- Silicones are stable to temperature. Their physical properties, which are refractive index, surface tension, density, viscosity, change little in high temperature.
- They are very good spreading ability on fiber surface.
- Silicone treatments have positive effects on fiber, yarn and fabric modules. [18]

CHAPTER 4
DENIM FABRIC MANUFACTURING

Denim fabric is defined as a hard-wearing twill fabric, traditionally made from cotton but now also made in polyester/cotton and stretch types. The weave is usually 3x1 twill and a step tweel is produced by setting the warp yarns closer together than the weft. It was originally a protective clothing fabric but has now become accepted for leisure wear. [33]

Denim fabrics are developed by using entirely cotton yarns for clothing, and generally find extensive applications in the world [37]. Denim is comfortable, fashionable, affordable and durable and popular in all the age group. Denim is available in different weight ranges from 6 – 16 oz/sq yd which is categories as light denim 10-12 oz/sq yd., heavy denim 14-16 oz/sq. yd. [23]

4.1. Process Flow For Denim Manufacturing

In weaving structure, length-wise yarns called warp, and the width-wise yarns called filling yarns. When the warp yarn used in denim fabrics compared with the conventional woven fabrics the warp yarns is uniquely prepared for denim manufacturing. The yarn goes through numerous processing steps before it is placed on the weaving machine. Unlike the warp yarn, most filling yarn is put onto yarn packages and delivered directly to the weaving machine where it is inserted into the fabric without any further preparation in the same manner as conventional woven fabrics. Traditional denim fabrics are woven by interlacement of indigo dyed warp and grey weft. Denim fabrics are made with open end rotor yarn in both warp and weft direction. However, ring yarn, ply yarn, filament yarn, lycra core yarn are extensively used in denim to achieve some special effect, smoothness and comfort in denim products. Process flow for warp yarn in denim manufacturing can be seen on Figure 4.1. Denim fabric manufacturing starts with the yarn spinning. Denim fabric is made from cotton and the step of the yarn spinning is equal to cotton spinning processes. This figure shows that the necessary steps in the manufacture of denim fabrics, beginning with the production of the warp yarns used. [5, 25]

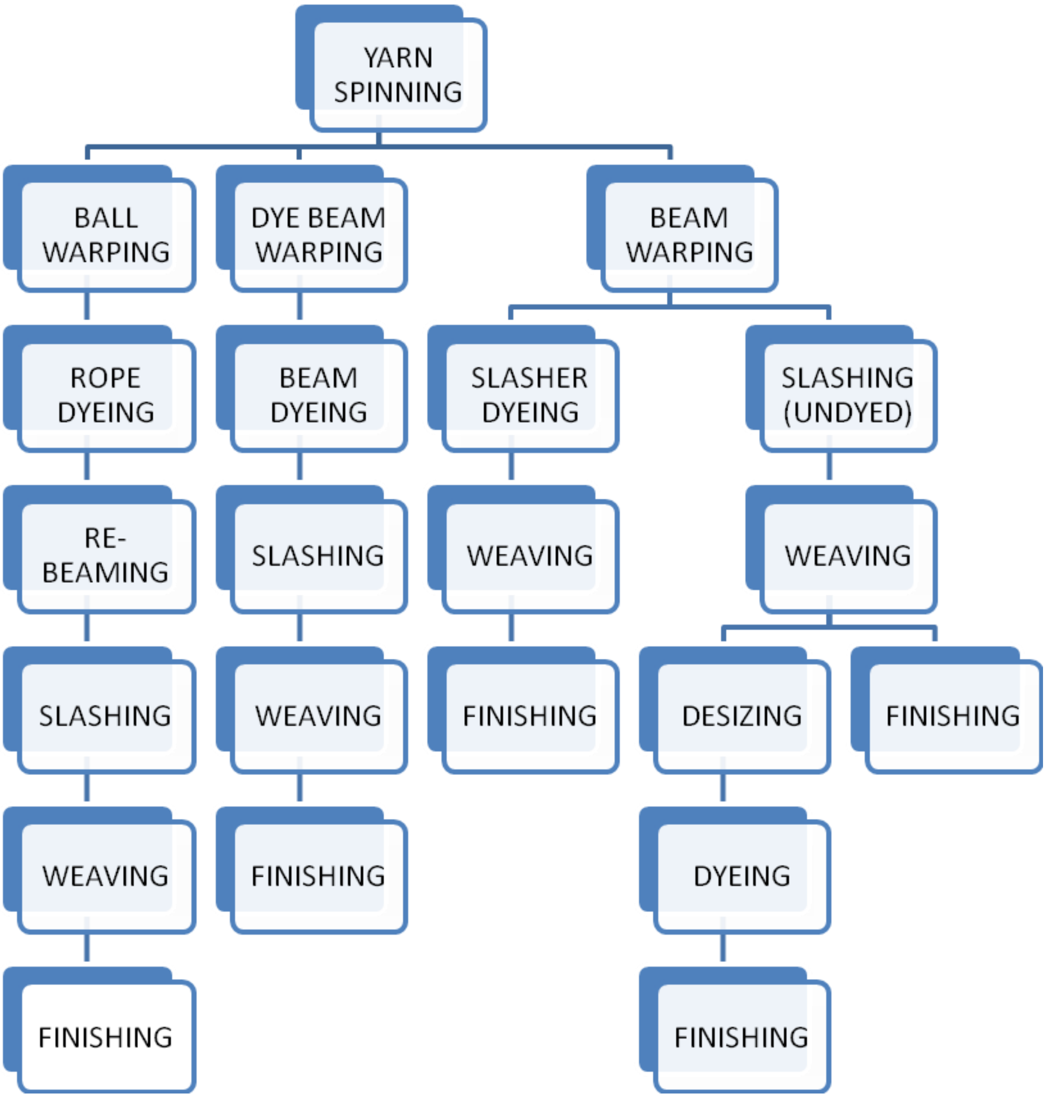

Figure 4.1: Process flow for warp yarn in denim manufacturing

4.2. Weaving Structure of Denim Fabrics

Denim fabrics are woven fabrics. Weaving is the most commonly used method of fabric construction. In weaving two sets of yarns are interlaced at right angle to one another in an established sequence, as shown in figure 4.2 As mentioned before, yarns in length-wise or in the machine direction are called warp yarns or warp ends, and these are interlaced with filling yarns or picks. The row or order of interlacing the two sets of yarns can be varied to produce many different weave designs. The finished fabric construction is determined by the number of warp and filling yarns per square inch or centimeter. This thread count along with the yarn counts used will influence fabric properties such as weight, fabric tightness, cover, drape, hand, tensile strength, tear strength, and other fabric properties.

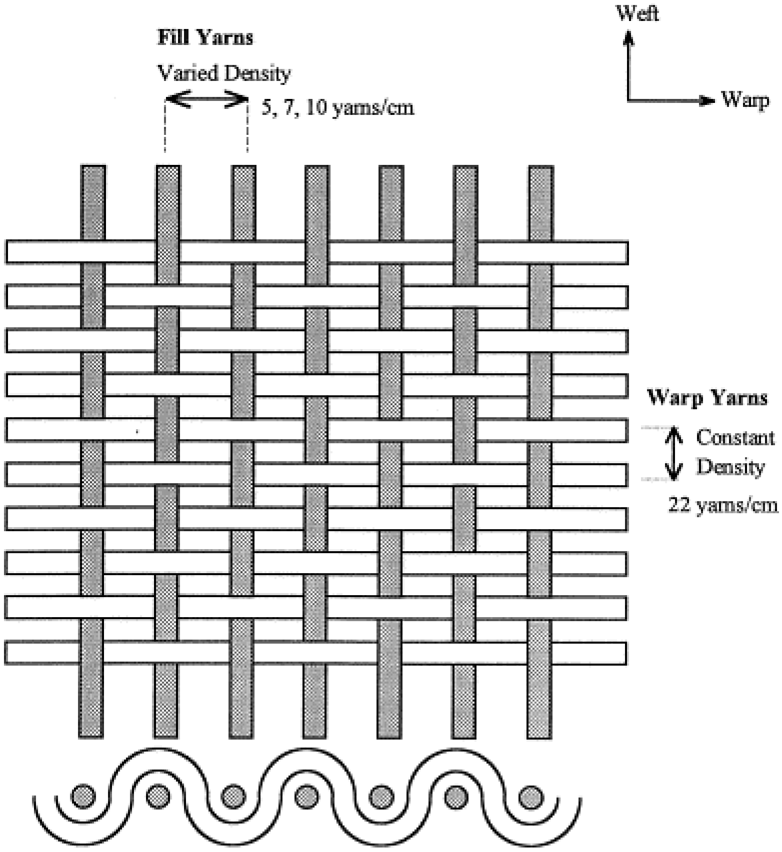

Figure 4.2: Woven fabric structure

Typical Denim Constructions, Weaves, and Weights

The classical construction of a bottom weight 14.5-ounce denim is 60-64 warp yarns per inch and 38-42 filling yarns per inch. The count of the yarn in the weaving affects the fabric weight, fabric weave design and the tightness of the fabric. And also influencing the fabric weight is the amount of size left on the finished fabric. Other denim fabrics and denim “look-a-likes” may vary in construction from 52 to 70 warp yarns per inch and from 36 to 52 picks per inch. Generally, denim is woven as 3/1 twill, 2/1 twill, 3/1 broken twill, or 2/2 broken twill. According to these type of weave designs, the weights of these finished denim fabrics can vary between 3.5 and 16.5 ounces per square yard. The weight of the fabric is important to determine what the final garment application will be:

- 3.5-8.0 ounces per square yard – blouses, tops, shirts, and top of bed fabrics
- 8.0-16.5 ounces per square yard – trousers, jeans, jackets, and upholstery

The traditional denim is a 3/1 RHT warp faced fabrics, a variety of denim fabric are made with different weave designs, such as 2/1 twill weave, broken twill, zig-zag twill, reverse twill etc. Today, denim fabrics are also manufactured with fancy design in order to meet the latest fashion. With the help of the twill weave, several classes of fabrics can be made. 3/1, represent what each warp yarn is doing relative to the filling yarns that it is interlacing with. In this case, each warp yarn is going "over" three picks and then "under" one pick. Traditionally denim is a warp face 3/1 twill, 2/1 twill fabric. The twill may be left handed twill (LHT) or right handed twill (RHT). If the twill line is rising to the right, and the fabric is known as a right- hand twill weave. If the twill line is made to rise to the left, then the design is left-hand twill. (Figure 4.3) [10, 25, 26]

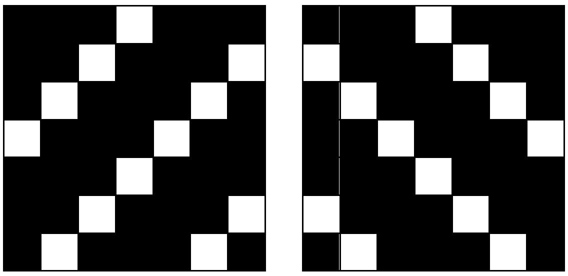

Figure 4.3: Diagram of 3/1 right and left hand twills

<u>Non-conventional Denim Fabric Constructions</u>

Indigo-dyed yarns have been woven in plain weaves known as chambray, oxfords, baskets, herringbones, bedford cords, and combinations of 3/1 and 1/3 twills. Jacquard designs and dobby weaves have also been incorporated into denim designs to produce new looks and textures. As fashion designers create new ideas, the fabric manufacturers have to follow the demands of marketing teams and market leaders.

4.3. Dyeing and Slashing Warp Yarns for Denim

4.3.1. Rope Dyeing

Most denim fabrics have warps which are dyed with indigo dye and the filling yarns undyed. For the fabric performance and the overall fabric look, there are a number of modifications or alternatives in the dyeing process. With the initiation of denim garment washing techniques, the consistencies of the indigo dyeing process and its modifications have become crucially important in determining the quality and performance of indigo denim products.

Indigo (C.I. Vat Blue 1) is a vat dye which was probably one of the oldest known coloring agent. It has been used to dye cellulosic textiles especially cotton. This blue dye is still employed extensively today for dyeing cotton yarn in the manufacture of denims and blue jeans. [9]

The properties of the indigo dye account for the wide variety of color designs that are available on denim materials. Indigo is a vat dye and it is unique as a major textile dye, because of its low affinity for the cellulose fiber like cotton. Because of the low substantivity of the indigo, the balls warp dyeing process ring dyes cotton. Unlike almost all other commercially successful dyestuffs, the indigo dye concentrates in the outer layers of the cotton yarn and fiber during the dyeing process. This produces an intense ring of color around a white core in the cotton yarn and the cotton fiber thus the name ring dyeing. When using most other dyes, if the ring-dyeing effect occurs, it would be considered a dyeing defect. [10]

Indigo, extracted from leaves of the plant *Indigofera tinctoria*, and Tyrian Purple from Mediterranean sea snails of the genera *Murex* and *Purpura*, are water-insoluble pigments called vat dyes. For dyeing of cotton yarn, indigo should be converted into water-soluble "leuco" form in chemical reduction process. The soluble, reduced form of the dye is called a leuco derivative. Leuco Indigo has substantivity for wool and cotton fibers. After dyeing, air oxidation of the pale yellow leuco dye, absorbed in the fibers, regenerates the dark blue, insoluble pigment trapped inside them. Because of this, the fastness to washing is very good in comparison to most natural dyes.

Figure 4.4: Indigo dyeing steps

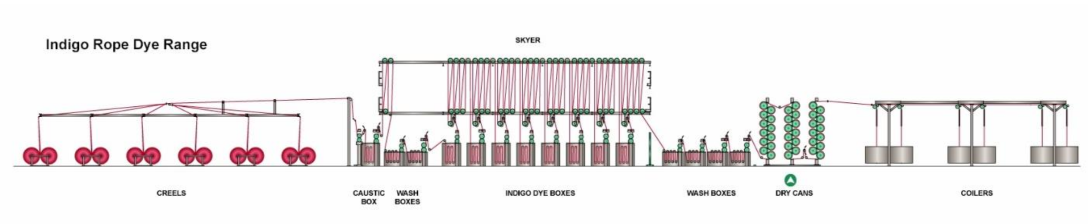

Figure 4.5: Indigo dye range [20]

In rope dyeing, ball warps are continuously fed into the rope or chain-dyeing range (Figure 4.5) for application of the indigo dyeing. In figure 4.5 the flow diagram of rope dyeing has shown. The rope dyeing system offers highest production. Because, this system is a continuous process and there is no stoppages for set changes. The ropes are first fed into scouring baths. The ropes passed through one or more scouring baths which consist of wetting agents detergents and caustic. The purpose of these scouring baths is to remove the dust, dirt, minerals, ash, pectin and waxes which are naturally occurring impurities found on the cotton fiber. It is very important to remove these impurities to get uniform wetting and uniform dyeing. The ropes are subsequently fed into one or more water rinsing baths.

If a sulfur bottom is required at this point, the ropes of yarn are fed into a bath of a reduced sulfur dye. Like indigo dyes, sulfur dyes are water insoluble. That is why they have to be reduces to a water soluble form before application. Unlike indigo, the sulfur dye can penetrate into the core of the cotton fiber/yarn. The aim of this process is to give the indigo dyed yarns a much deeper and darker shade or to slightly change the shade of the blue yarn to make it unique. Once the reduced sulfur dye is applied to the ropes, they are skyed to allow the dye to oxidize into its normal water insoluble form. [24, 25]

Then, the ropes of yarn are fed into the indigo dye baths and they skyed after each dip. For removing any unfixed dye, the ropes of yarn are rinsed in several water baths. If a variant type of yarn color is desired, sulfur dye can be added at this point. Similar to the bottom-dyeing process, this process is known as a sulfur top. Although the sulfur dye will migrate towards the core of the fiber/yarn, the sulfur top gives a different type of yarn color performance when garment washed than a sulfur bottom. The sulfur top process is then followed by a water rinse to remove any unfixed dye.

After either rinsing following indigo dyeing or rinsing following sulfur topping, the yarn ropes pass through squeeze rolls for extracting the water in mechanic way. By the way, the yarns become dried and coiled into large tubs. The typical type of drying apparatus is a multiple stack of drying cans. Maintaining a stable pressure of steam within the cylinder can accurately control the temperature of the surface of each cylinder. Care must be taken not to attempt to dry the rope of yarn too quickly, which causes the dye to migrate to the surface of the rope. Additionally, if the surface of the drying can is too hot, the yarn can be overstressed producing an undesirable glazed appearance that reduces absorbency in later processing. Over-drying of the yarns will weaken them considerably adversely affecting re-beaming, slashing, and weaving.

After drying process, the color of the yarn is checked by visually or instrumentally. In many modern indigo dye ranges, the color of the yarn can be monitored by instruments continuously. These systems are electronically linked to the controls of the indigo dye baths. This type of systems can automatically adjust the dynamics of the process to obtain the most stable color from the beginning to the end of the dye lot.

Denim manufacturers prefer using consecutive (sequential) dyeing technique to make the color variability minimum between the denim fabric panels after garment washing. Basically, this method is based on the concept that the color properties of indigo-dyed yarn processed at a specific time, most closely resemble the color properties of the indigo yarn processed just before and just after that lot. This method has proven much more effective at minimizing color variability in garment washing when compared to the technique of shade sorting alone. [10, 24, 25]

4.3.2. Slasher Dyeing

According to some manufacturers, the rope or chain dyeing of indigo is not possible or desirable. Because of that reason, many different types of equipment have been tried as an alternative to the dip and sky method of the rope dye range. The slasher dyeing has overcome as an alternaticve method. Slasher dyeing is a range which is applied size formulations onto warp yarns before weaving. This range shown in figure 4.6, consists of section beams of warp yarn, which are forced into a sheet of yarn. The first feeding of the yarn sheet is into a scouring section. In the scouring section the natural impurities are removed. The next section is for application of the indigo. In order to achieve fairly deep shades, the indigo is applied in a series of multiple dip and sky applications to allow for shade build up. If the arrangement of the slasher dyeing does not allow for multiple dip and sky applications. Then only light and medium shades can be obtained from indigo. After the application of dye, process is continued by after washing and drying. With some machinery arrangement, warp size for weaving is immediately applied. In other arrangements, the warp size is applied onto the yarns employing a separate range. [10, 21]

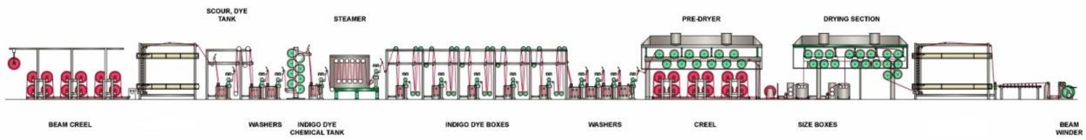

Figure 4.6: Slasher indigo dye range

4.3.3. Beam Dyeing

Beam dyeing is a dyeing technique that has been used for dyeing warp yarn for denim. Beam dyeing technique shown in figure 4.7. In this technique, perforated core beam is used. The warp yarns are wound parallel to each other around the perforated beam with flanges on each end. After that, the beam is loaded into a sealed cylindrical dye vessel, so dye liquor can be pumped through the perforations in the beam and then through the yarn. After dyeing, standard procedure for cleaning is applied; so the yarn is washed, extracted, dried, and added to other beams for slashing and weaving.

Beam dyeing technique does not provide itself to the unique dyeing properties of indigo, so it is normally used with other dye types including reactives, directs, sulfurs, and vats resulting in a wide range of colors. This is also a well known and accepted technique for many different constructions of cloth, but in denim applications, it has mainly been employed for dyeing yarns in colors rather than indigo. [10]

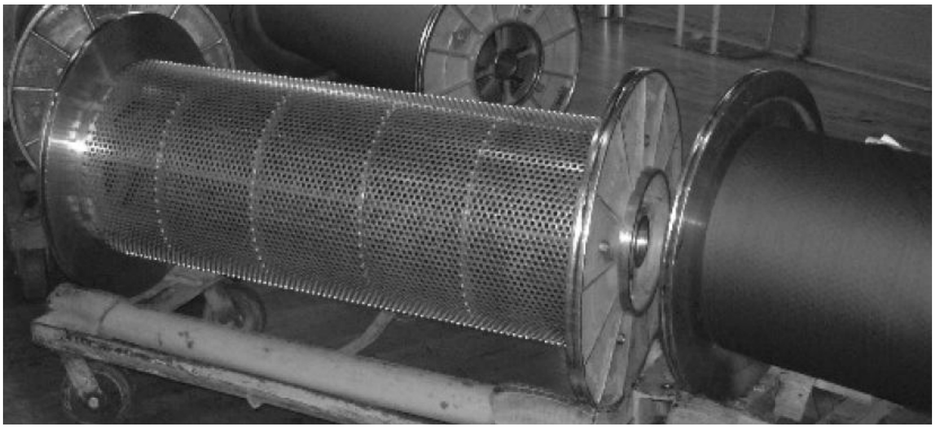

Figure 4.7: Dye beams

4.3.4. Undyed Denim

Without any dyeing process, denim fabrics can be sold. These types of denim fabrics are called “bull denims”. Bull denims are known as natural denims. Their color is off-white cream which is comes from natural color of the cotton. After finishing, cutting, and other apparel production steps, natural denims can be used like traditional denim garments, or they can go through garment dyeing and other wet processing to yield various properties. However, these garments will not show the color contrast effects shown by traditional denim garment processing. Also, these natural denims can be bleached to yield “white denim” products. [10]

CHAPTER 5
EVALUATION OF SEWING QUALITY

Fabric quality is an important criterion for the high quality production but it is not necessary in alone. Stitching is a common operation in garment sewing process, where two pieces of fabrics are joined together to make a three dimensional shape. **[39]** During stitching operation, selection of a suitable sewing thread and sewing needle, suitable stitch type, optimization of sewing parameters will affect the wearing comfort of the finished garment.

In apparel industry, the sewing process is one of the critical processes in the determination of productivity and the quality of the finished garment. [26] Sewability is the ability of a fabric to be sewn without holes and drapes. Sewing damage is usual problem that affects the textile and clothing industries. [36]

The quality and performance of a sewn garment depends on various factors such as seam strength, slippage, puckering, appearance and yarn severance. All these factors combined together contribute to sewability of the fabric which is considered to be one of the most important aspects of clothing science. [3]

Fabrics are flexible structures that have external factors introduced into them during make up. Sewing threads, machine settings and operator handling are all important factors that influence the performance of a fabric during sewing. [32]

The study of sewability in clothing in manufacture in general and its importance, particularly in denim based clothing, has considerable relevance in today's advanced garment manufacturing process. Modern garment manufacturing processes use motorized high speed sewing machines, which exert very high tensions in the thread and also high forces of penetration of needles in the fabric. As a result, both sewing thread and the yarns in the fabric get abraded/severed during seam process. The extent of damage becomes more critical if the fabric being used is of a dense, thick and heavy construction such as denim. At the same time, if the sewing thread is not properly selected with respect to the construction of the fabric and nature of treatment the thread will get during sewing, the seam performance will deteriorate in the final garment. In the context of denim based garments, particularly trousers and jackets, sewing thread is not only used for joining the fabric but also for decorative purposes along seam line. The thread poses a linear projection on the surface of the garments and is subjected to more abrasion than the garment. Therefore, unless the sewing thread chosen for a denim garment is stronger, it may break before the fabric does. [3]

5.1. Sewing Damage

Producing good quality seam, getting the functional and aesthetic performance of the seam are the result of all these factors:

1. Stitch type
2. Machine Settings
3. Needle Type
4. Type of Sewing Thread
5. Machine operator
6. Fabric Parameters [31]

These parameters are important to sew fabrics together without damages. Sewing damage refers to needle cutting or yarn severance in the fabric during sewing. Seam damage caused by the needle penetrating through the fabric can create severe sewability problems.

Needle Damage, in sewn fabrics, the partial or complete yarn severance or fiber fusing caused by a needle passing through a fabric during sewing. [1]

Some types of fabric faults in seaming may be attributed to the sewing needle. The grater the force produced by the thrusting needle, the higher is the number of problems during sewing. This determines the fabric sewability. During sewing of woven fabric, good sewability implies that warp and weft yarns are separated by the needle going through them without producing fabric damage. When warp and weft densities are high, yarns are either broken or separated by needle as a result of the pressure against the neighbouring yarns (ends or picks). [29]

In any finished apparel product, seam damages are not acceptable. Because seam damages may reduce seam strength, generate poor appearance. Seam damage is measured by the Needle Cutting Index, sewing threads are removed from the sewn specimen. The count of the number of fabric yarns and the count of the number of fused yarn in the direction perpendicular to the direction of sewing are used. [3]

5.2. Needle Cutting Index

Needle Cutting is the breaking of yarns in the fabric as the needle enters the seam. When the needle enters the seam, the needle point should not cut the yarns but push them aside as it penetrates the fabric. Needle shift the yarns to one side.

The seam damage test was conducted according to ASTM-D 1908 test method for needle related damage due to sewing in woven fabrics, on the SCOPE TEK DCM510 magnification system. For each sample, needle cutting index was determined using the following formula:

$$\textit{Needle cutting index } (\%) = \frac{\textit{number of yarns cut/inch}}{\textit{number of yarns in fabric/ich}} \text{ x } 100 \qquad \text{(Eq.1) [1]}$$

5.3. Needle Size

The needle size refers to the diameter of the needle. There are different needle size systems in the apparel industry such as the metric system. The metric system is the simplest and most widely used in the apparel industry. A higher the metric count represents a greater needle diameter. A higher needle size may be the cause of seam damage because there is more possibility of breaking the fabric yarn when using a needle with greater diameter. However, due to the use of lower needle size the chance of sewing thread strength loss and/or breakage is high (because of friction between sewing thread and needle eye, which, in turn, reduces the seam strength and/or seam efficiency. [28]

CHAPTER 6
MATERIAL AND METHOD

6.1. Denim Fabric Properties

Denim fabric samples were produced by GAP Güneydoğu Tekstil San. ve Tic. A.S. in Malatya. The physical parameters of the denim fabrics we used in the study are given in Table 6.1.

Table 6.1: Denim fabric properties used in study

Weave	**Fabric Sett (WarpxWeft) / cm**	**Warp Count x Weft Count (Ne)**	**Weight (onz)**
3/1 Z twill	32 x 25	11 x 11	11.5

6.2. Softener Details

Three different silicone softeners which have different particle sizes were selected for the study. The silicone softeners for this work were produced by CHT Tekstil Kimya San.Tic. A.Ş. and properties of these silicones are given in Table 6.2.

Table 6.2: Properties of used Silicone Softeners

Chemical used	**Type**	**Commercial name**	**Density (g/cm^3)**	**≈ pH**
Silicone 1 (Micro)	Nonionic	Tubingal RBC	1.01	4.2
Silicone 2 (Semi Macro)	Nonionic	Arristan 65	1.00	4.5
Silicone 3 (Macro)	Nonionic	Arristan 444	1.00	4.5

6.3. Method

6.3.1. Application of Silicone Softeners

The softener application has done with padding system. The objective of padding is to impregnate the fabric with a solution of softener chemical. As shown in the Figure

6.1 a padder consists of a narrow trough, which is slightly wider than fabric, and a pair of rubber-covered rollers under pressure. The fabric passes through the pad trough, where it is saturated with silicone solution, and then between rollers, where the pressure squeeze air through of the fabric and the solution into it.

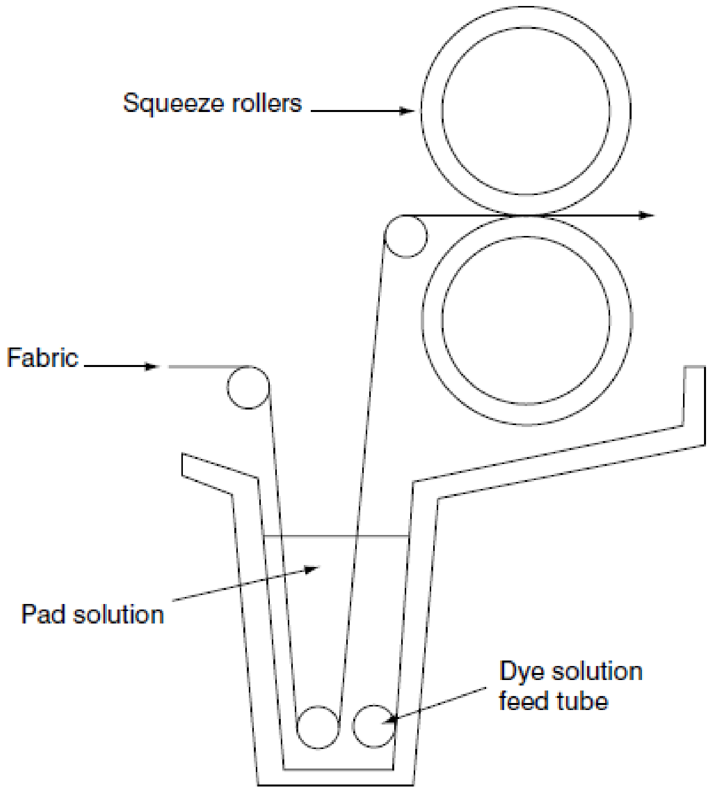

Figure 6.1: Schematic view of the padder

During padding, the fabric passes into the solution and then squeezed to remove excess solution. With this procedure the mechanical impregnation of the solution can be achieved. This application must be uniform. The uniformity of the distribution of any chemical in the padded fabric depends on having a constant immersion time in the bath and between bath and squeeze rollers. The bath level must remain constant during the fabric running through. The fabric speed must also be constant too. These requirements provide the uniform and successful padding.

Fixation procedures involve heating the material in saturated steam, in hot air, or by contact with heated metal cylinders. Fixation is achieved by heating the padded fabric in saturated steam for 20-60 s. [5]

Silicone application was conducted in an uncontrolled industrial environment by İnternet Tekstil A.Ş. in Adıyaman. For elimination of the hydrophobicity of the woven denim fabric, the samples rinsed with anionic wetting agent with a solution of 0.5 gr/lt. After rising, fabric pH was measured as 6.

For silicone applications, 3 different silicone baths have been prepared as following:

20 lt water + 0.60 lt silicone

The pH of the every silicone bath was measured individually before application and after application and shown in Table 6.3.

Table 6.3: pH Values of the silicone baths

Softener	**pH (Before Application)**	**pH (After Application)**
Silicone 1	5.5	6
Silicone 2	5.5	6
Silicone 3	6	6

For silicone softener application an industrial Brückner Stenter was used. (Model 2005, 52 mt long, 8 drying rooms). Application was done with the following details:

Temperature of rooms : 140^0C – 150^0C

Application time : 120 – 150 seconds (2 passages)

6.3.2. Particle Size Analyze of the Silicone Softeners

The particle size measurements of the softeners were performed with a Brookhaven Instruments 90 Plus (Holtsville, NY / USA) using dynamic light scattering technique which is based on simply to pass a beam of light through a colloidal dispersion. When this happens, the particles or droplets scatter some of the light in all directions. When the particles are very small compared with the wavelength of the light, the intensity of the scattered light is uniform in all directions (Rayleigh scattering); for larger particles (above approximately 250nm diameter), the intensity is angle dependent (Mie scattering). If the light is coherent and monochromatic, as from a laser for example, it is possible to observe time-dependent fluctuations in the scattered intensity using a suitable detector such as a photomultiplier capable of operating in photon counting mode. These fluctuations arise from the fact that the particles are small enough to undergo random thermal (Brownian) motion and the distance between them is therefore constantly varying. Constructive and destructive interference of light scattered by neighboring particles within the illuminated zone gives rise to the intensity fluctuation at the detector plane which, as it arises from particle motion, contains information about this motion. Analysis of the time dependence of the intensity fluctuation can therefore yield the diffusion coefficient of the particles from which, via the Stokes Einstein equation, knowing the viscosity of the medium, the hydrodynamic radius or diameter of the particles can be calculated. [14]

To determine the particle size of silicone softeners, an emulsion was prepared by diluting the softener in distilled water in a ratio of 1:10; then, polyacrylic measuring cell of Brookhaven 90Plus was filled with approximately 4 mL of the emulsion and it was located in the measuring cuvette of the instrument without shaking or mixing to get laser beam pass through. The instrument applies dynamic light scattering technique. Dynamic light scattering is applied for almost three decades for studying dispersed systems. The software applied in the apparatus of Brookhaven Instr., gives multimodal size distribution basing on the autocorrelation functions for the dispersed light of the laser beam (670 nm) along with polydispersity and effective diameter. Polydispersity is a measure of nonuniformity in the particle size distribution in the studied system. It results from the method of cumulant analysis. In this method no assumption is needed about distribution functions [28]. The basic equation is:

$$g(t) = \int G(\Gamma) e^{-\Gamma t} \partial\Gamma \qquad \text{(Eq.2)}$$

Where $g(t)$ is measured data, t is the delay time [28], $G(\Gamma)$ is dependent upon distribution of the particles, and Γ is defined as:

$$\Gamma = Dq^2 \qquad \text{(Eq.3)}$$

Here D is the translational diffusion coefficient, which is determined from the scattered light and Eq. (Eq.4) describes the quantity q:

$$q = \frac{4\pi n}{\lambda} \sin(\frac{\theta}{2}) \qquad \text{(Eq.4)}$$

In which n is the refraction index of the suspending liquid, θ is the scattering angle, and l is the wavelength of the laser light. Finally, the diffusion coefficient is related to the particle diameter d.

$$D = \frac{kT}{3\pi\eta d} \quad \text{(Eq.5)}$$

Where k is Boltzmann constant, T is absolute temperature, and η is the suspending liquid viscosity. The exponential in Eq.2 is expanded in a Taylor's series about mean value and then integrated giving a general result. Then the logarithm of the autocorrelation function can expressed as a polynomial in the delay time t. The t powers in Taylor's series are called 'cumulants' of the distribution and they are identical to the 'moments of distributions'. It appeared that practically only first two of them are of reliable meaning. Eq.3 expresses the first cumulant and the second is given by:

$$\mu_2 = (D^2 - D^{*2})\, q^2 \quad \text{(Eq.6)}$$

Here D^* is the average diffusion coefficient. Thus, the effective diameter is calculated from Eq.5 and $\mu 2$ moment allows calculation of the variance of the 'intensity' weighed distribution of diffusion coefficient. It gives information about width of the size distribution; more practical is use relative width, i.e. reduced second moment, which is called 'Polydispersity' [30].

$$\text{Poly.} = \mu 2 / \Gamma^2 \quad \text{(Eq.7)}$$

This is dimensionless magnitude and is close to zero for almost monodisperse sample. For narrow distributed sample it is ca. 0.02–0.08, and becomes higher for broader distributed samples.

As said above the analysis is based on the intensity of scattered light that is proportional to number of particles N present in the suspension, and having diameter d and mass M. Moreover, the particle shape (if not spherical) factor $P(q, d)$ has to be taken into account (for q see Eq. 4). The factor is equal to 1 for particles much smaller than the wavelength (<60 nm) as well if the measurements are extrapolated to 0° angle. The diffusion coefficient distribution can be expressed following:

$$D = \Sigma N M^2 P(q, d)\, D \,/\, \Sigma N M^2 P(q, d) \quad \text{(Eq.8)}$$

The sums deal with all particles in the sample. Because mass M (or volume) is related to the diameter d in third power, the average, called 'effective diameter' results as [30]:

$$D_{eff} = \Sigma N d^6 / \Sigma N d^5 \quad \text{(Eq.9)}$$

if P(q, d)=1 has been assumed. Similarly, it can be defined number average diameter:

$$d_n = \Sigma N d / \Sigma N \quad \text{(Eq.10)}$$

area average diameter:

$$d_a = \Sigma N d^3 / \Sigma N d^2 \qquad \text{(Eq.11)}$$

and weight average diameter:

$$d_w = \Sigma Nd^4 / \Sigma Nd^3 \qquad \text{(Eq.12)}$$

From Eqs. (Eq.9), (Eq.10), (Eq.11) and (Eq.12) it results that $d_n \leq d_a \leq d_w \leq D_{eff}$, and equality occurs only for monodisperse sample. The bigger differences between the calculated diameters are the broader distribution of the particles in the sample exists. However, although the values are relative, for the same sample all the diameters can be used to characterize the sample. Moreover, the software has option for multimodal size distribution, which applies Non-Negatively constrained Least Squares (NNLS) algorithm with which the solution of Eq. 1 is a more general. It applies the approach of Grabowski and Morrison [12]. With this algorithm the weight (or volume), surface and number fractions from the intensity fractions, first scattering factors have to be calculated. They are obtained by Mie method, but here additionally to the suspending liquid refractive index, the complex refractive index of the particles has to be taken into account.

The duration of the measurement was around 5 minutes. The wavelength of the laser light was 670 nm. The size distributions were determined at **90^0** of the scattering angle of the laser beam and the measurements were carried out at 25^0C room temperature.

Figure 6.1 : Brookhaven 90Plus particle size analyzer

6.3.3. Sewing the Samples and Needle Damage Observation

Fabric specimens were prepared according to the ASTM – D 1908 test standard. They were cut into specimens in warp and weft direction. Fabrics sewed in lock stitch industrial sewing machine with 120 no. sewing thread by using three different needle sizes (N12, N14, and N16). The specimens of each fabric were sewn face to face in warp and weft direction. The tension of the bobbin thread and needle thread were adjusted. The sewing geometry was determined. Lock stitch has been made with 120 no sewing thread by Brother (S-6200D) electronic industrial sewing machine. Stitch density was fixed to 5.5 stitches/cm.

After sewing, the sewing thread is then removed from the seam to prepare warp wise and weft wise samples.

The seam damage test was conducted according to ASTM-D 1908 test method for needle related damage due to sewing in woven denim fabrics, on the SCOPE TEK DCM510 magnification system. Warp and weft seams were investigated individually by counting the damaged yarns within samples and needle cutting index (%) values were calculated according to Eq.1.

6.3.4. Statistically Evaluation

The contribution of needle size and softener type, having factors of both with 3 treatment levels, were assessed using a complete the randomized two way analyze of variance (ANOVA). The results were evaluated at 5% significance level.

We evaluate the results based on the F-ratio and probability of the F- ratio the lower the probability of the F-ratio, the stronger the contribution of the variation and the more significant the variable. The treatment levels were marked in accordance with mean values, and any levels marked by same letter showed that they were not significantly different.

CHAPTER 7
RESULTS AND DISCUSSION

7.1. Particle Size Analysis Results

The particle size distribution graphs of silicone softeners used according to intensity (%), volume (%), and number (%) are given in Figure 7.1 - 7.3 and their effective diameter (Deff) values by intensity are given in Table 1. The effective diameter is the diameter that a sphere would have in order to diffuse at the same rate as the particle being measured. It can also be called "equivalent sphere diameter". If the system is polydisperse, the effective diameter is an average diameter, and if weighted by intensity, it is an averaged intensity of scattered light by each particle. The effective diameter may result from one or more populations of the particles present in the emulsions. From the multimodal size distributions, it appears that in the investigated softener emulsions, there was almost only one population of particles resulting with single and narrow peak. For the microsilicone, the main fluctuation was around 14 μm with high intensity (91.4 %) and a second peak appeared around 301 μm with relatively small intensity (8.6 %). For the semi-macro and macro silicone softeners, there were fluctuations around 20 and 25 μm, respectively both with 100% intensity and they caused bigger Deff values. Table 1 also shows the polydispersity (PDI) values of the softeners. For homogeneous emulsions this value approaches zero; so the lower the polydispersity the higher the homogeneity of the particle size of the emulsion. The measurements states that the softeners employed in the study differed in particle size and the most homogeneous emulsion belonged to the macro silicone softener.

Table 7.1: D_{eff} and PDI values of silicone softeners

Name	**Average Measurement**	
	Size (μm)	**PDI**
Silicone 3	25.05	0.0795
Silicone 2	20.71	0.1245
Silicone 1	14.515	0.235

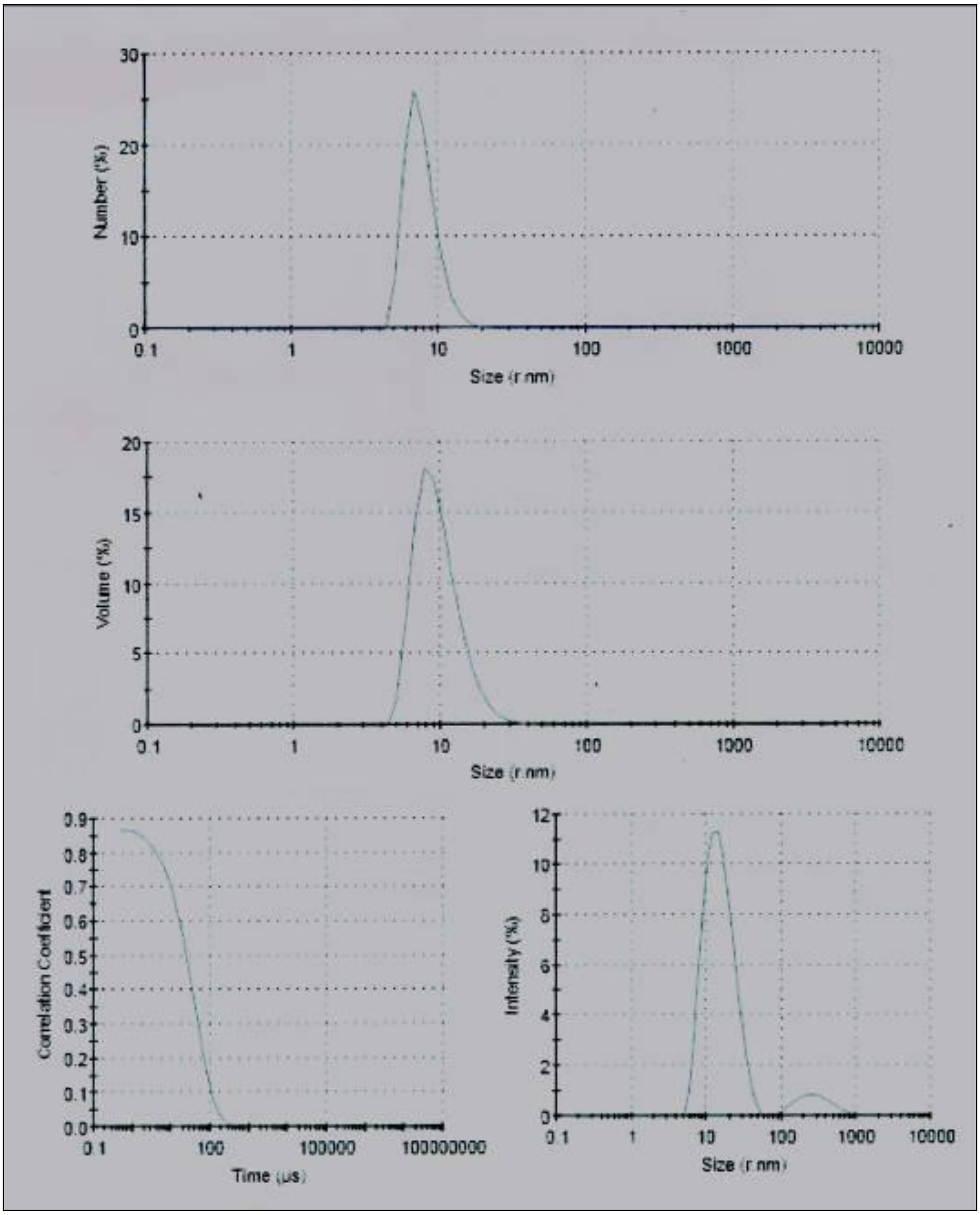

Figure 7.1: Silicone 1 - Micro silicone softener graphs

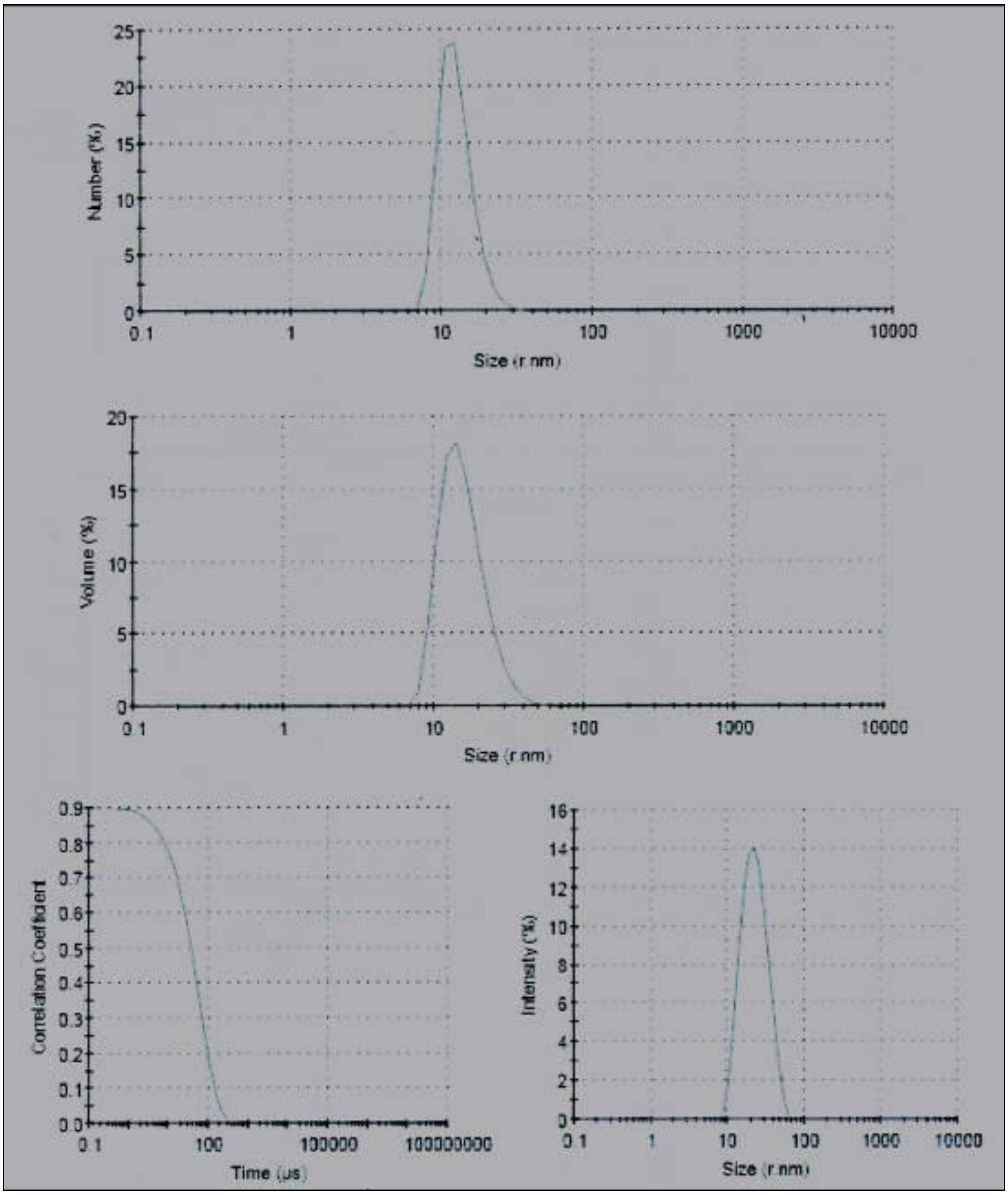

Figure 7.2: Silicone 2 - Semi silicone softener graphs

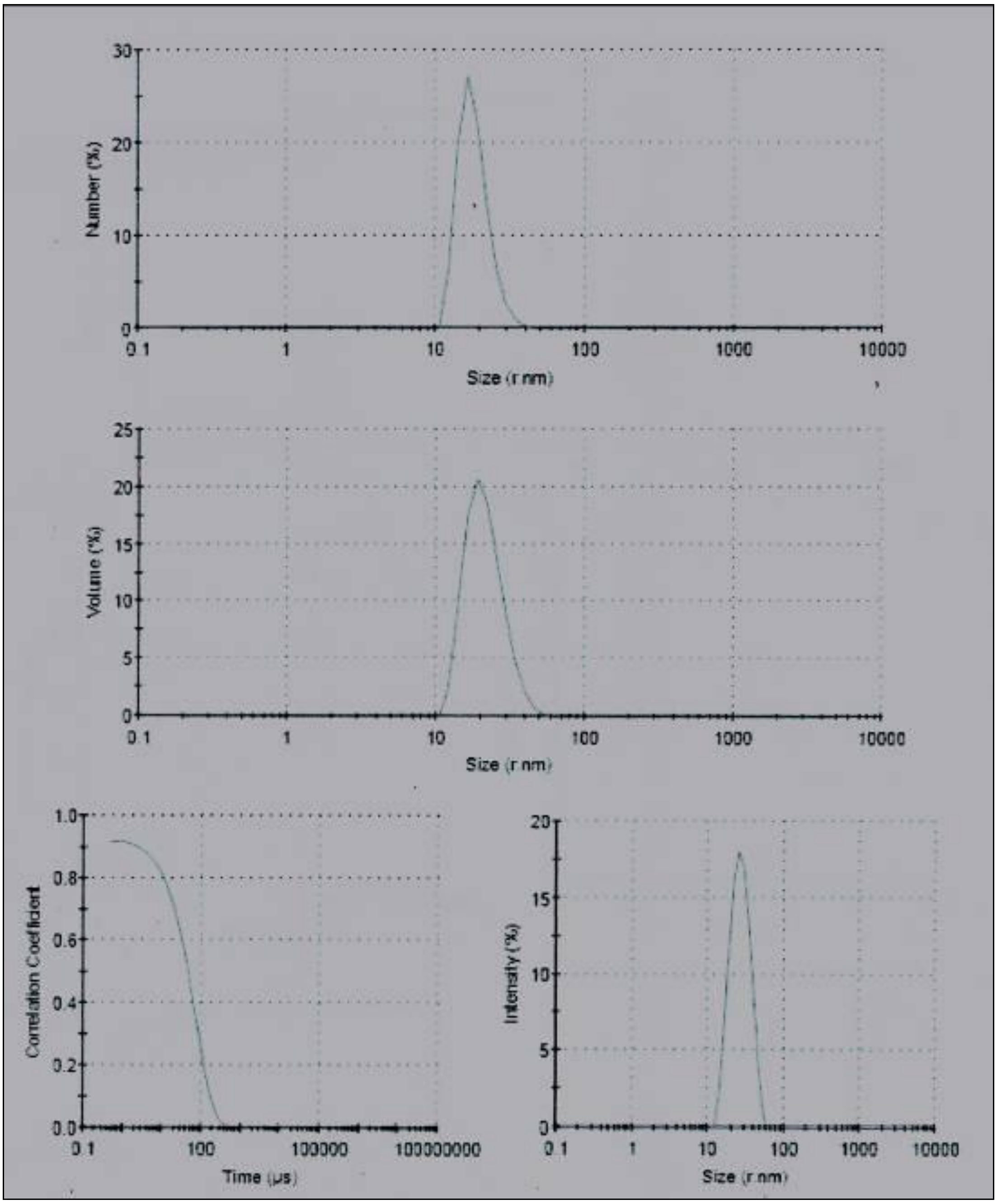

Figure 7.3: Silicone 3 - Macro silicone softener graphs

7.2. Needle Cutting Index:

According to observation of the needle damages on denim fabric with SCOPE TEK DCM510 magnification system, needle cutting index (%) values determined are given on Table 7.2.

Table 7.2: Needle Cutting Index Values (%)

			Silicone Softener Type		
	Needle Size	**Without Silicone**	**Silicone 3**	**Silicone 2**	**Silicone 1**
Damage (weft direction)	12	35.12	33.25	16.62	20.75
	14	36.24	29.13	12.50	16.62
	16	44.20	20,75	29.12	25.00
Damage (warp direction)	12	33.25	17.54	29.12	23.33
	14	29.15	23.33	23.33	17.54
	16	33.25	29.12	29.12	29.12

Changes in needle size have an impact on the fabric damage which is treated with (macro) silicone 3. It is obvious that the increasing the needle size has an effect reducing the needle damage. Also damages in warp direction on the macro silicon treated fabric are increasing according to the increasing of the needle size.

When we examine the (semi) silicon 2 treated fabric damages on weft direction we can see that the needle size does not have an obvious effect on the needle cutting index. We can also observe that, needle cutting index does not have values regular increasing or decreasing. Figure 7.4 shows the needle cutting index on the weft direction.

When we analyze the needle cutting index on the warp direction, the increasing of the needle size has an effect of the increasing the damages on the (macro) silicon 3 treated fabrics. For fabrics treated with (semi) silicone 2 and (micro) silicone 1 softener, the values are not clear to asses. Needle size does not follow any specific trends with the silicone particle size. The results of the needle cutting index on the warp direction are shown in Figure 7.5.

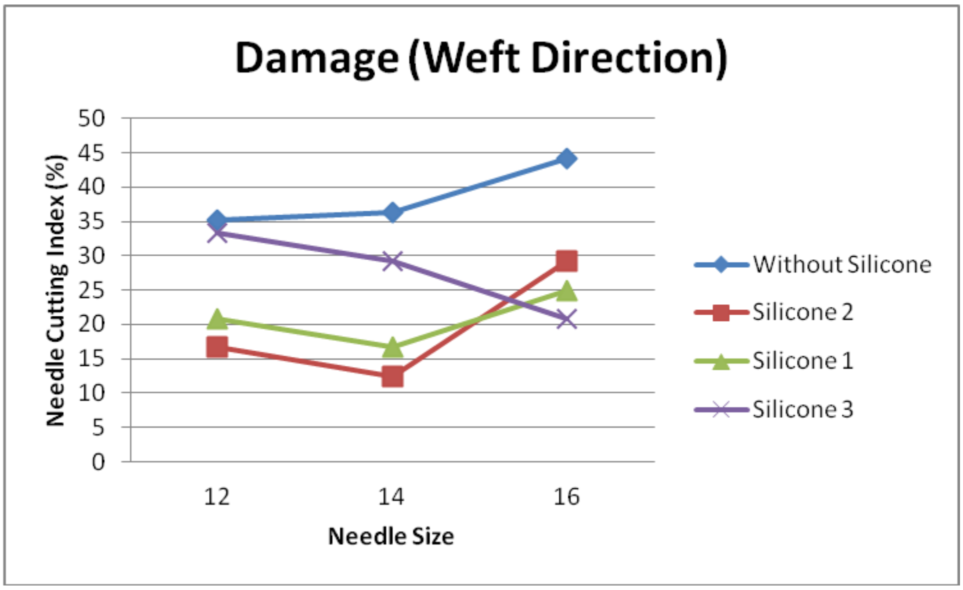

Figure 7.4: Results of the needle damages on weft direction

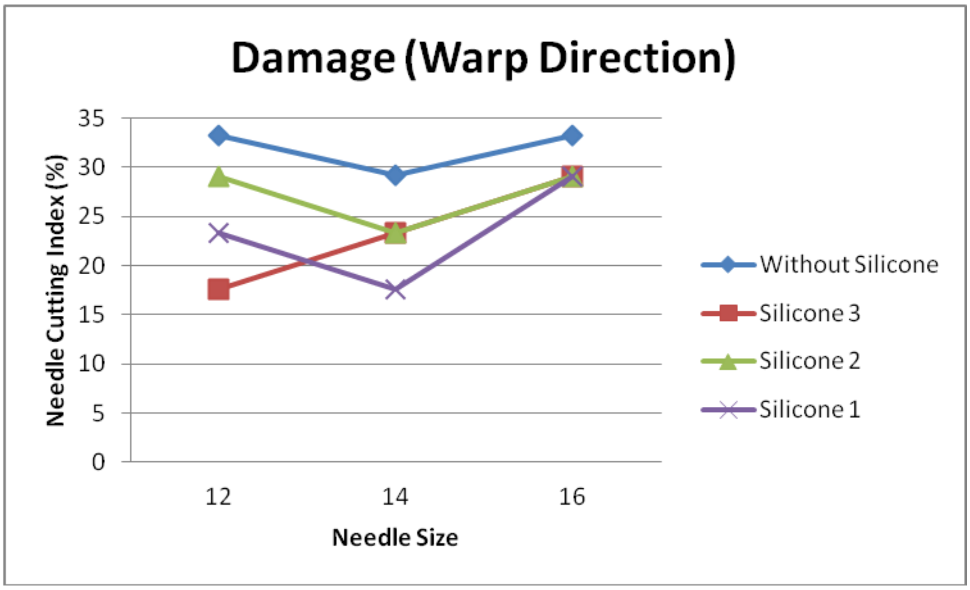

Figure 7.5: Results of the needle damages on warp direction

It is obvious that the fabric damages percantage of the warp direction is higher than the weft direction for every needle size. There was no clear trend obtained at for needle cutting index (%) values for samples treated with different particle size of softeners but this is concluded to nonsignificant contribution of softener type as indicated in statistical analysis.

As the needle number (thickness) increased the differences between NCI (%) values of treated samples decreased which is concluded to the higher contribution strength of needle type than that of softener type.

The graphical view of the needle cutting index according to needle size is separately given on Figure 7.6 – 7.11.

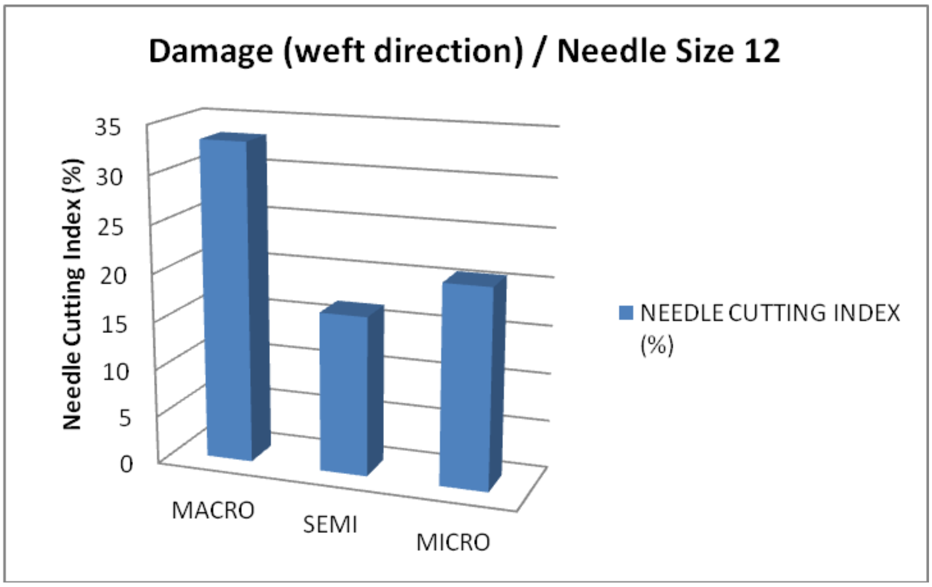

Figure 7.6 : Results of needle cutting index for the needle size 12 on weft direction

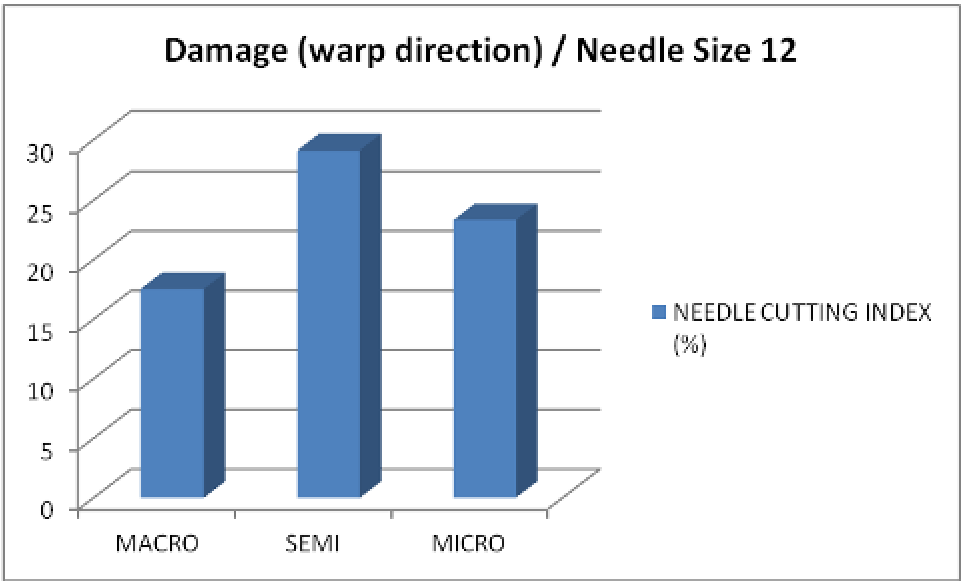

Figure 7.7 : Results of needle cutting index for the needle size 12 on warp direction

When we examine the needle cutting index for the needle size 12, using (macro) silicone 3 reduced the needle damages on weft direction. For the needle size 14, we can make the same comment accordingly. This shows that, for the needle size 12 and 14 we can use macro silicones for denim fabric apparel production. It will save the cost.

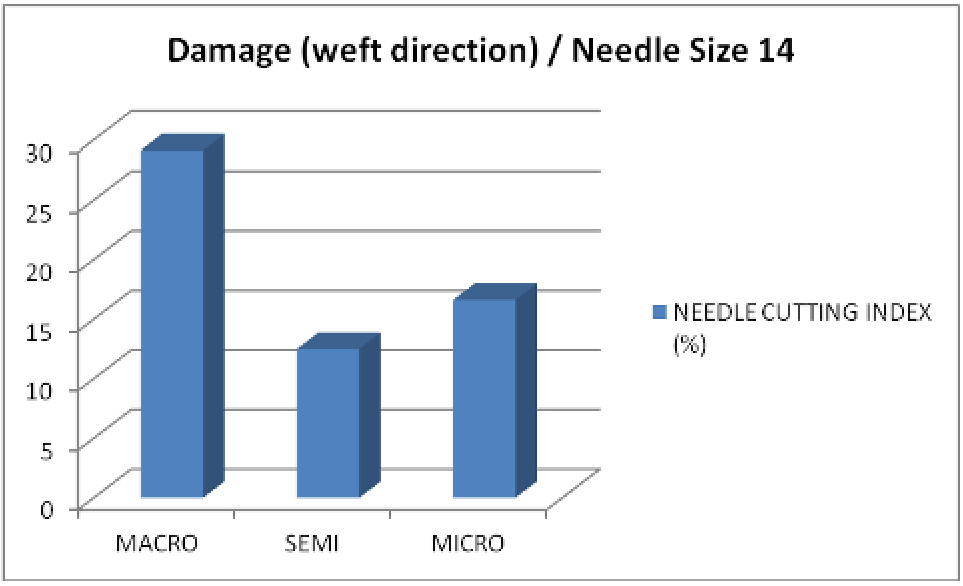

Figure 7.8 : Results of needle cutting index for the needle size 14 on weft direction

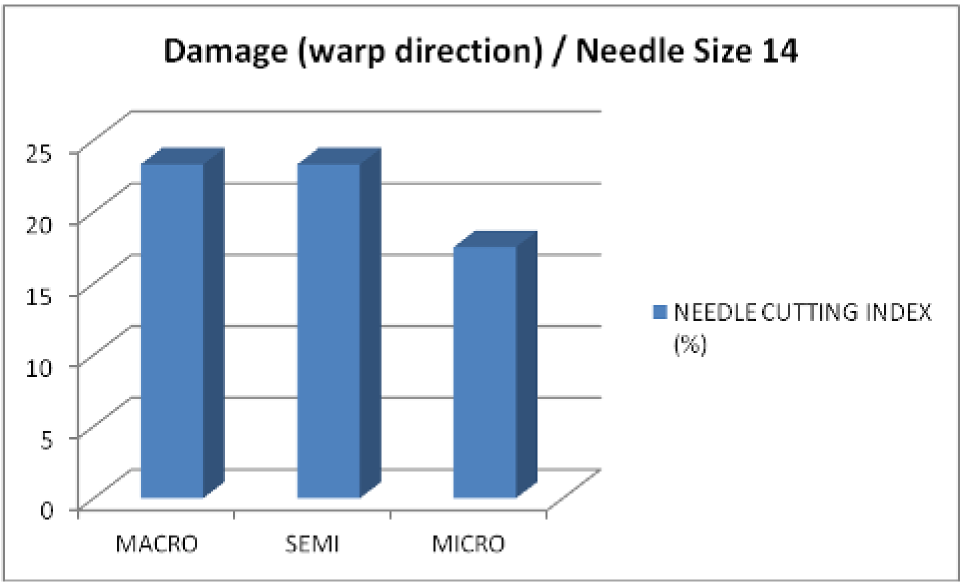

Figure 7.9 : Results of needle cutting index for the needle size 14 on warp direction

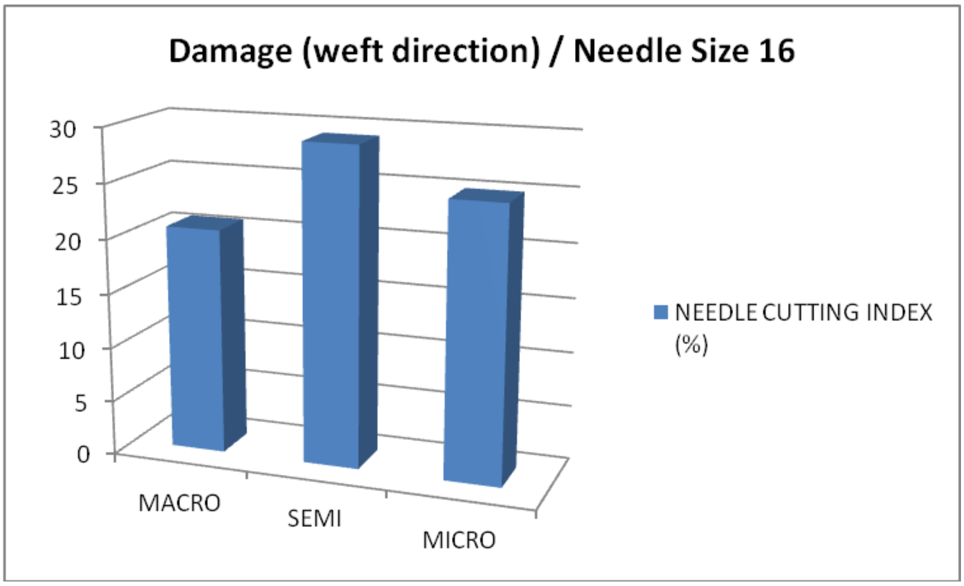

Figure 7.10 : Results of needle cutting index for the needle size 16 on weft direction

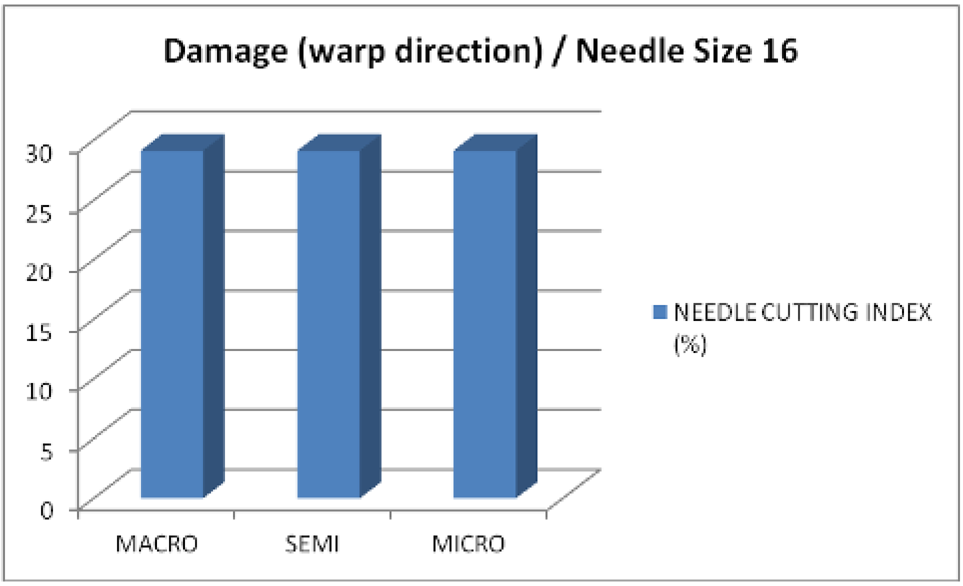

Figure 7.11 : Results of needle cutting index for the needle size 16 on warp direction

When we examine the needle cutting index values for the weft and warp direction with needle size 16, we found that the particle size of the silicone softeners does not give significant results. It can also observed that needle cutting index is higher when denims are sawn by needle 16. This is because of the higher diameter of the needle causes more mechanical restraint and deformation of the yarns in the fabric.

Silicone treatment has an effect on needle cutting index. This can be attributed to the reduction in the mechanical restraint in the denim due to silicone finish.

Illustration of the needle damage is given in figure 7.12. Needle damages observed by an optical microscope and photographs were taken. Appearance of the needle perforations in the fabric construction (weft and warp direction) can be shown in Figure 7.13 – 7.16

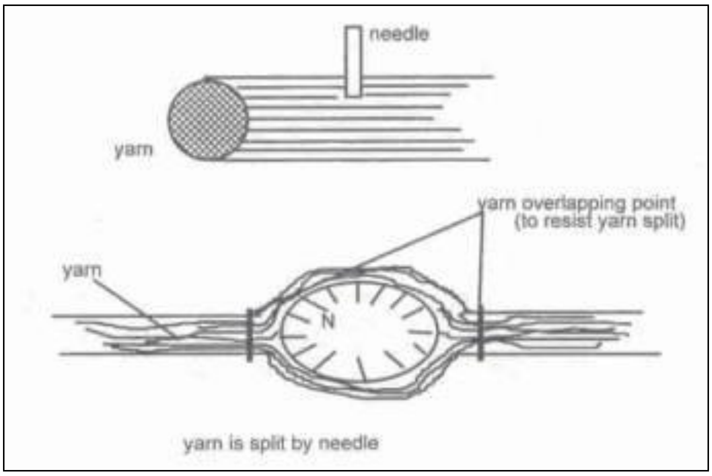

Figure 7.12: Illustration of the needle damage

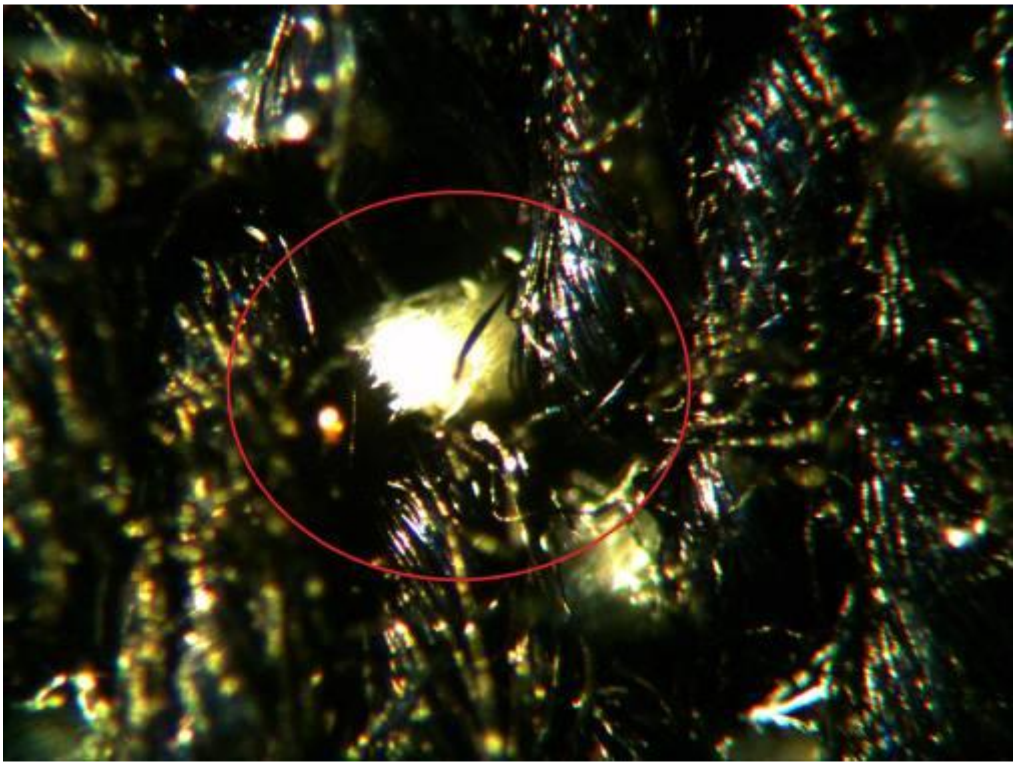

Figure 7.13: Needle damage photo

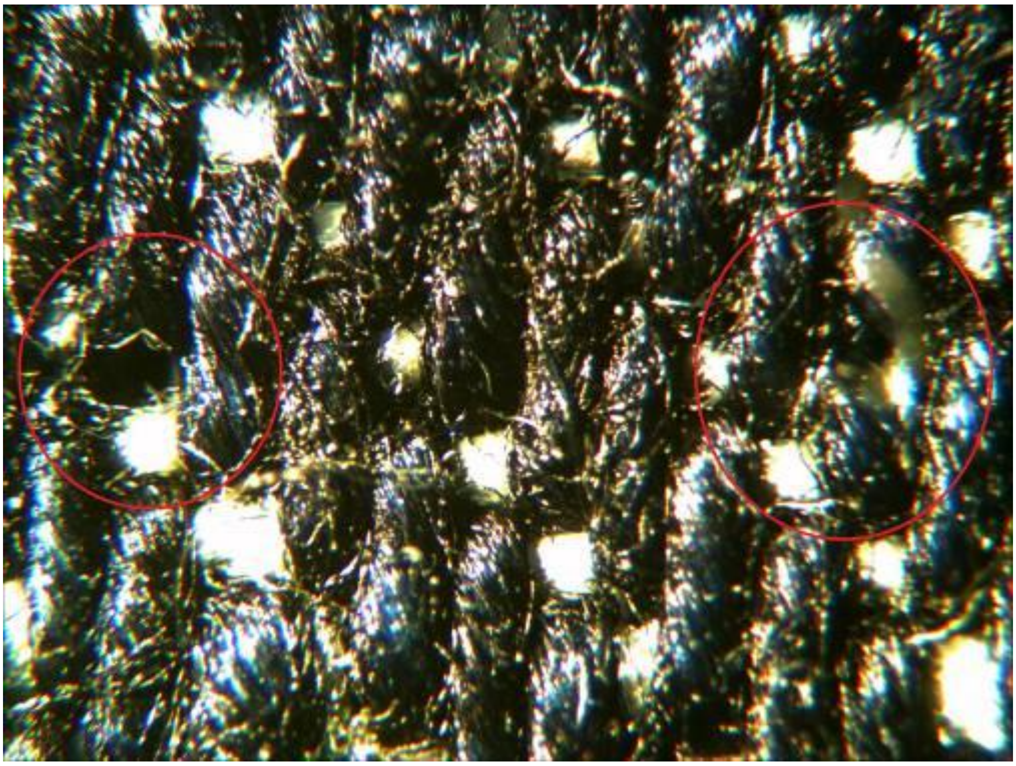

Figure 7.14: Needle damage photo (Macro silicone, needle size 12, sewed in warp direction)

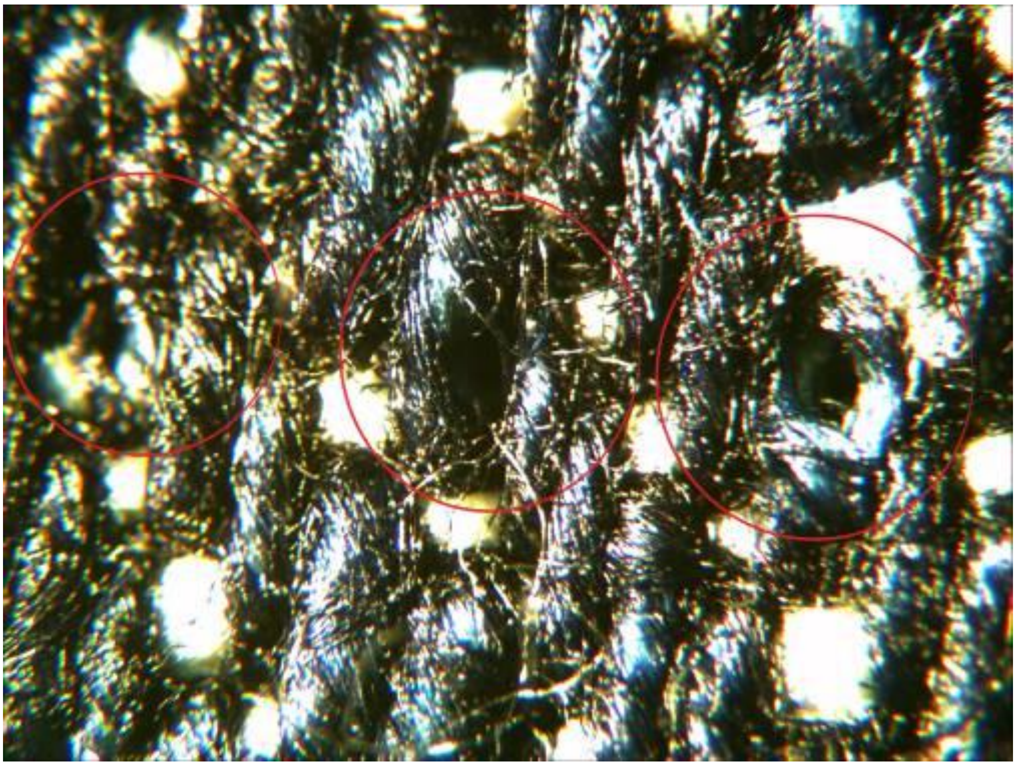

Figure 7.15: Needle damage photo (Macro silicone, needle size 12, sewed in warp direction)

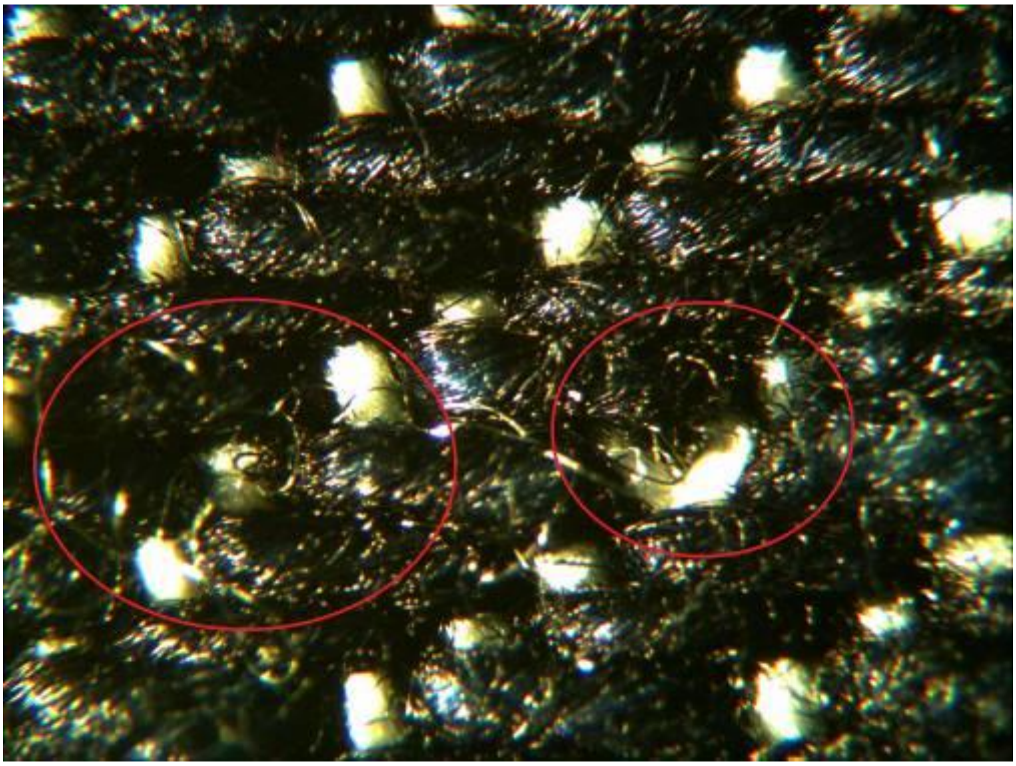

Figure 7.16: Needle damage photo (Macro silicone, needle size 16, sewed in weft direction)

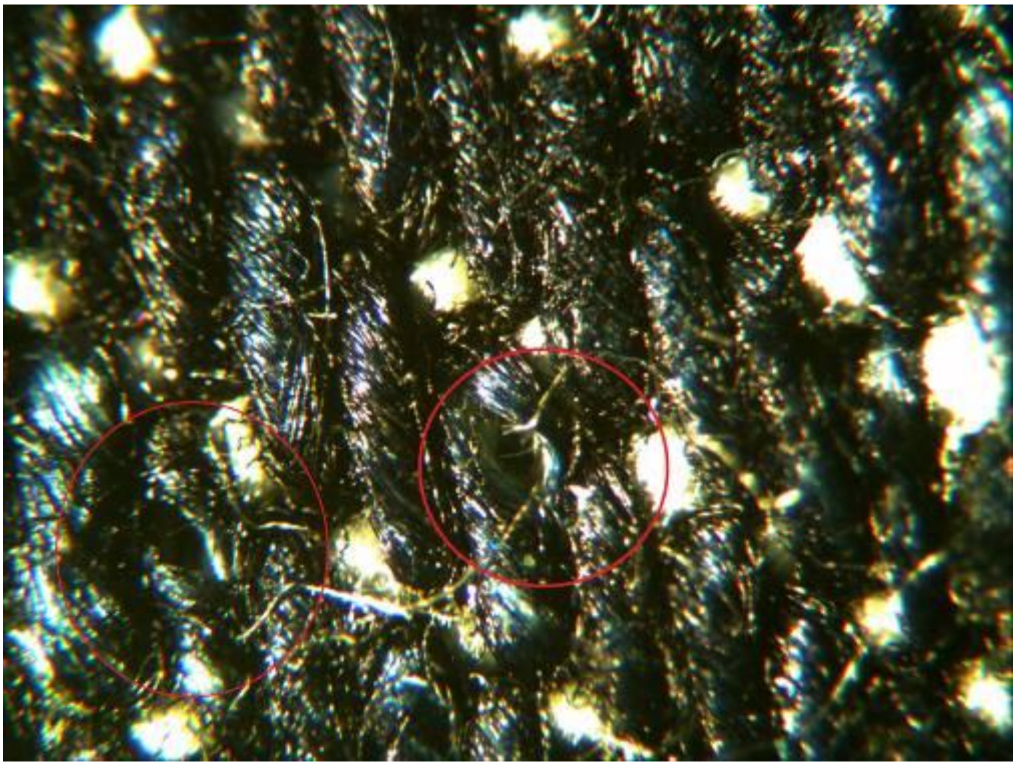

Figure 7.17: Needle damage photo (Semi silicone, needle size 16)

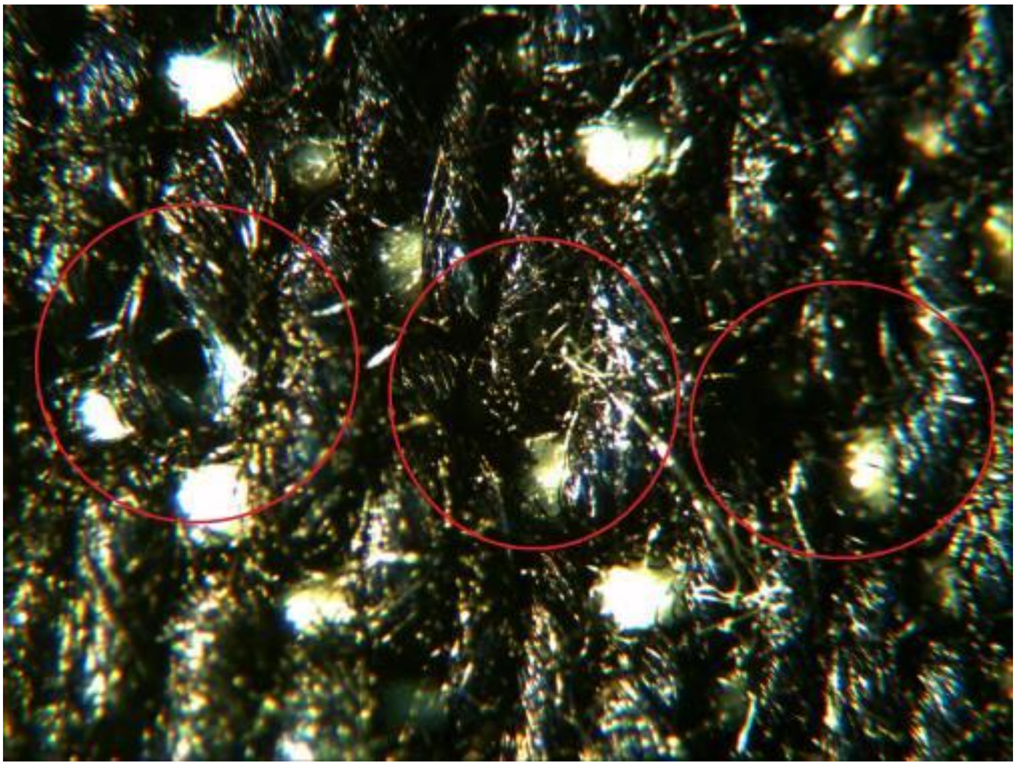

Figure 7.18: Needle damage photo (Micro silicone, needle size 12, sewed in warp direction)

7.3. Statistical Analysis

All test results were evaluated separately as given on Table 7.4 – 7.5.

Table 7.3 and Table 7.4 show that both needle and softener types have non-significant affect on needle cutting index as a function of sewing damage on denim fabrics. This means that any change in needle or softener type does not change the contribution on needle cutting index and it is contributed to high fabric sett (courser yarns and higher fabric density) property of denim which gives quite high resistance to needle cutting. Besides, softener type seems to have stronger contribution on needle cutting index than needle size at warp direction since it has higher estimated variance / mean of squares (MS) value than that of needle size; however it is vice versa at weft direction.

For the needle effect on the both weft and warp wise does not have any specific trends. We can say that the needle effect on the needle cutting index is almost same for the both weft and warp wise. But, when we examine the softener effect, using the softener gives less needle damage on warp wise.

Table 7.3: COSTAT analysis of needle cutting index on warp direction for needle and softener

	Source	ss	df	MS	F	P	
main effects	**Needle**	0.96	2	0.48	1.85	-	ns
	Softener	0.29	2	0.14	0.57	-	ns
interaction	**needle x softener**	0.59	4	0.14	0.57	-	ns

Table 7.4: COSTAT analysis of needle cutting index on weft direction for needle and softener

	Source	ss	df	MS	F	P	
main effects	**Needle**	1.55	2	0.77	2.1	-	ns
	Softener	2	2	1	2.7	-	ns
interaction	**needle x softener**	4.44	4	1.11	3	-	*

The results of these experiments were evaluated at %5 significance level and the SNK tables are given on Table 7.6 – 7.9.

When the needle penetrates the fabric, weft or warp thread damage will occur. The penetration effect is related with the frictional characteristics. Because of that reason, we expected that using bigger needle for sewing would increase the needle-related damage. When we compare the needle size effect on the needle cutting index on the weft and warp wise we can observe that the (%) needle cutting index at warp direction is higher than weft direction for every needle size. Thus, it is concluded that weft and warp density of denim fabrics are important when considering needle cutting index.

Table 7.5 – 7.6 show that although needle size is found to be non-significant, using size16 needle during sewing causes more needle-related damages at warp direction and size14 needle gives the least needle cutting index for both fabric direction.

Table 7.5: SNK analysis of needle cutting index on warp wise for needle size

Rank	Trt#	Mean	n	ns
1	3 (no 16)	20.8	9	a
2	1(no 12)	16.6	9	a
3	2(no 14)	15.3	9	a

Table 7.6: SNK analysis of needle cutting index on weft wise for needle size

Rank	Trt#	Mean	n	ns
1	1(no 12)	37.02	9	a
2	3 (no 16)	35.09	9	a
3	2(no 14)	27.19	9	a

As mentioned before, frictional characteristic of the fabric has important effect on needle-related damage. Using silicone finishes reduces the friction during sewing.

The SNK tables (Table 7.7 and Table 7.8) points that the particle size of softener is non-significant on (%) needle cutting index of denim fabric at both warp and weft directions and macro silicone softener gives the lowest (%) needle cutting index at warp and semi-macro silicone softener at weft direction. It is also clear that needle cutting index values at weft direction are quite higher than warp direction for each softener types.

Table 7.7: SNK analysis of needle cutting index on warp wise for softener particle size

Rank	Trt#	Mean	n	ns
1	2 (semi)	19.4	9	a
2	1 (micro)	16.6	9	a
3	3 (macro)	16.6	9	a

Table 7.8: SNK analysis of needle cutting index on weft wise for softener particle size

Rank	Trt#	Mean	n	ns
1	1 (micro)	38.95	9	a
2	3 (macro)	32.98	9	a
3	2 (semi)	27.19	9	a

7.4. Conclusion

In this study, we investigated the effect of the particle size of silicone softeners and the needle size effect on needle cutting index at denim fabrics. For this study we used three different size sewing needle and three different silicone softeners (macro, semi, micro) on single type of denim samples. The evaluation of the needle cutting index was done according to ASTM –D 1908 standards and microscopic the observation of the damages, caused by the needle, was done.

Finally, the results of this study are:

1. Both needle and softener types have non-significant affect on needle cutting index as a function of sewing damage on denim fabrics. This concluded to high density of denim fabrics which compensates the contribution of needle and softener on needle cutting index. The previous papers in the literature stated that needle size is significant on plain fabrics [15] which points different finding from ours also plain fabrics were found to have higher warp and weft needle damage index values than denim fabrics. Another study showed that [34] silicone finishes reduced the needle cutting index on denim fabrics however they did not focus on particle size or softener type which is again defined as a difference from our study.

2. Needle cutting index (%) at warp direction is higher than weft direction for every needle size and softener type. This is contributed to higher warp density of the denim samples. This finding is confirmed by several researchers [15, 34] for both denim and plain fabrics.

We assume that this study can be expanded by the following suggestions as future work:

1. To investigate the contribution of various denim construction (weave, yarn type, yarn number and density, elastane yarn usage etc.)

2. To investigate the contribution of different chemical type of softeners

3. To investigate the contribution of other sewing parameters like seam density, needle shape, stitch type and sewing thread count.

REFERENCES

[1] ASTM – D 1908 Standart Test Methof for Needle-Related Damage Due to Sewing in Woven Fabric

[2] Bajaj P. (2000). Finishing of Textile Materials, *Journal of Applied Polymer Science*, Vol. 83 631–659

[3] Behera, B.K., Rathee, P.(1997). Sewability of Denim, *International Journal of Clothing Science and Technology,* Vol. 9, No. 2, pp.128-140.

[4] Bellini, P., Bonetti, F., Franzetti, E., Rosace, G., Vago, S. 2001. Finishing. Milano: Acimid

[5] Broadbent, A.D. 2001.Basic Principles of Textile Coloration. Society of Dyers and Colourists

[6] Carr C. M. 1995. Chemistry of the Textile Industry, Chapman & Hall, London

[7] Case F. (2006) Silicones in Fabric Care, *Inform*, V 17 No.9 553–616

[8] Choudhury R.A.K., Chaterjee B., Saha S., Show K., (2012). Comparison of Performances of Macro, Micro and Nano Silicone Softeners, *The Journal of The Textile Institute*, V103 No.9

[9] Choudhury, A., Roy K. 2006. Textile Preparation and Dyeing. Jersey: Science Publishers

[10] Cotton Incorporated. 2004. Technical Bulletin. ISP1010 Denim Fabric Manufacture. North Carolina

[11] Finishing Course Notes, Uludag University

[12] Grabowski, E.F., Morrison,J.D., (1983). Particle Size Distributions from Analysis of Quasi-Elastic Light Scattering Data.Wiley, New York

[13] Grancaric A. M., Lima M., Vasconcelos R., Tarbuk A. (2005) Handle of Cotton Knitted Fabrics – Influence of Pretreatments , 5^{th} World Textile Conference AUTEX

[14] Gunesoglu C., Kut D., Orhan M. (2010).Performing the Electrospraying Process for Application of Textile Nano Finishing Particles. *Textile Research Journal,*V 80, No. 5, 106-115

[15] Gurarda A., Meric B. (2005). Sewing Needle Penetration Forces and Elastane Fiber Damage during the Sewing of Cotton/Elastane Woven Fabrics. *Textile Research Journal*, Vol. 75, No. 8, 628-633

[16] Henault B., Elms R. A.,(2000) Silicone: Expanding Opportunities for a Performance-Enhancing Material in the Detergent Industry, Dow Corning Corporation.

[17] Herard, R. A. 1979. Textile Chemists Colorist, Vol 11 No.6, 24-128

[18] Heywood, D. 2003. Textile Finishing. Society of Dyers and Colourists, Bradford

[19] Holme I. (1993) New Developments in the Chemical Finishing of Textiles, *Journal of the Textile Institute*, V84 No.4

[20] http://morrisontexmach.com/pops/indrope/indigo_rope_dye1st.htm. 03.09.2012

[21] http://morrisontexmach.com/sheet_dye.cfm. 03.09.2012

[22] http://www.fibre2fashion.com/industry-article/28/2765/silicone-finishes-for-textiles1.asp

[23] http://www.fibre2fashion.com/industry-article/29/2899/technology-of-denim-production-part-i1.asp

[24] http://www.fibre2fashion.com/industry-article/30/2919/technology-of-denim-production-part-ii1.asp

[25] http://www.fibre2fashion.com/industry-article/30/2966/technology-of-denim-production-part-iv1.asp

[26] http://www.textileschool.com/School/Weaving/DraftingPlans/TwillWeaves.aspx 2012.

[27] Hui P.L.C., Chan K.C.C., Yeung K.W. and Ng F.S.F. (2007). Application of Artifical Neural Networks to the Prediction of Sewing Performance of Fabrics. *International Journal of Clothing Science and Technology*. 19(5): 291-318

[28] Mandal, S. (2008). *Studies on Seam Quality with Sewing Thread Size, Stitch Density and Fabric Properties*. A M. Sc. Thesis. Institude of Textile and Clothing. The Hong Kong Polytechnic University

[29] Manich A. M., Domingues J. P., Sauri R.M. , Barella A. (1998), Relationships between Fabric Sewability and Structural, Physical and FAST Properties of Woven Wool and Wool Blend Fabrics, The Journal of the Textile Institude, V.89 Part 1 No:3

[30] Manual Instructions for 90Plus. (1995) Brookhaven Instr, Holtsville, Newyork

[31] McLoughlin J., Hayes S. , (2011), Computerised Reporting for Fabric Sewability, The Journal of the Textile Institude, V.102 No: 7 , p 621

[32] McLoughlin J., Sabir T., Hayes S. (2010) . Fabric Parameter Mapping for Seam Sewability, *International Journal of Fashion Design, Technology and Education,*Vol. 3 No.2, 77 - 88

[33] Miller E. (1992). Textiles Properties and Behaviour in Clothing Use. B T Batsford LTD. London

[34] Nayak R., Dadhye R., Gon D.B., (2010). Sewing Performance of Stretch Denim, *Journal of Textile and Apparel, Technology and Management*, V 6 No.3

[35] Schindler,W.D. , Hauser, P. J. 2004. Chemical Finishing of Textiles. Woodhead Publishing in Textiles. Cambridge England: CRC Press

[36] Stylios G., Fan J. (1991) An Expert System for the Prediction of Fabric Sewability and Optimization of Sewing and Fabric Conditions in Garment Manufacture, Ellis Horwood Ltd., Bradford

[37] Tokatlı N., (2007). Networks, Firms and Upgrading within the Blue-jeans Industry: Evidence from Turkey, *Global Networks,* V7 No1, 51 - 68

[38] Tomasino, C. 1992. Chemistry & Technology of Fabric Preparation & Finishing. Department of Textile Engineering, Chemistry and Science College of Textiles, North Caroline State University

[39] Tubbs, M.C., Daniels, P.N. 1991. Textile Terms and Definitions. 9 Ed. Manchester: The Textile Institute

[40] Xu T., Gu P. (2010), theoretical Analysis and Prediction of Overfeed Sewing Shrinkage of Wool-Type Fabrics, Journal of Fiber Bioengineering and Informatics, V.3 No: 3