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M.Sc. in Textile Engineering

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**UNIVERSITY OF GAZİANTEP
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NATURAL & APPLIED SCIENCES**

**ELECTROSPRAY FINISHING OF ALCOHOL REPELLENT
MATERIALS ON NON-WOVEN FABRICS AND
INVESTIGATION OF PERFORMANCE PROPERTIES**

**M.Sc. THESIS
IN
TEXTILE ENGINEERING**

**BY
SEMİH ÖZGEÇ
FEBRUARY 2017**

**Electrospray Finishing of Alcohol Repellent Materials on Non-woven Fabrics
and Investigation of Performance Properties**

**M.Sc. Thesis
in
Textile Engineering
University of Gaziantep**

**Supervisor
Prof. Dr. Ali KİREÇCİ**

**by
Semih ÖZGEÇ
February 2017**



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UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
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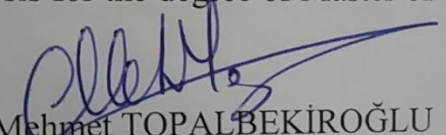
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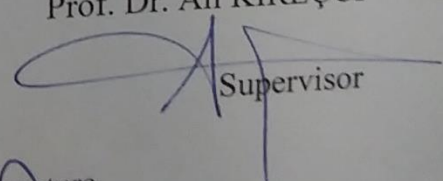
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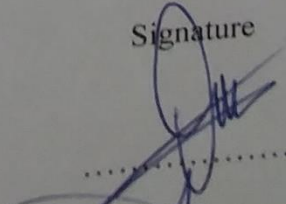
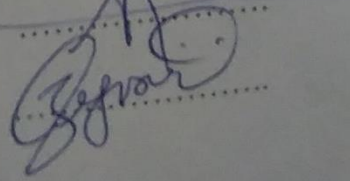
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Semih ÖZGEÇ

ABSTRACT

ELECTROSPRAY FINISHING OF ALCOHOL REPELLENT MATERIALS ON NON-WOVEN FABRICS AND INVESTIGATION OF PERFORMANCE PROPERTIES

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M.Sc. in Textile Engineering

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This research involves the comparison of the electrospray method, a new method for textile finishing operations, with conventional methods (pad-dry and kiss-roll) and the analysis of the results. The alcohol-repellent finish used in the production of medical textile fabrics is preferred for comparison between the methods. It is generally nonwoven fabrics are used in medical textiles since they are disposable fabrics, but sometimes woven fabrics are also preferred. Surgical aprons, covering and masks produced from these fabrics are intended to protect medical technicians and laboratory workers from blood and blood-borne pathogens or toxic chemicals and infectious agents. Today, various methods such as pad-dry, kiss-roll, foam application and spraying are used in textile finishing processes. Each method has its own set of handicaps such as non-homogeneous application of finishing, high cost and longer application time. Electrospray also has the potential to provide high energy savings due to low pick up. In this study, it was aimed to compare the performances of the methods and to determine the usage parameters of the electrospray method by applying alcohol repellent finishing to the non-woven and woven fabrics with 3 different methods (pad-dry-kiss-roll and electrospray). The alcohol repellency tests of fabrics were made according to the AATCC 193-2005 standard.

Key words: Elektrospray, pad-dry, kiss-roll, alcohol repellent, nonwoven and woven fabrics.

ÖZET
**ELEKTROSPREY BİTİM İŞLEMİ İLE ALKOL İTİCİ MALZEMELERİN NON-
WOVEN KUMAŞLARA UYGULANMASI VE PERFORMANS
ÖZELLİKLERİNİN İNCELENMESİ**

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Bu araştırma, tekstil bitim işlemlerindeki klasik yöntemlerden pad-dry ve kiss-roll'ün; kumaşlara farklı finisaj malzemeleri uygulamak için yeni bir yöntem olan electrospray metoduyla kıyaslanmasını ve bu yöntem için gerekli şartların karakterize edilebilmesini amaçlamaktadır. Yöntemler arasındaki kıyasın yapılabilmesi için uygulamalarda genellikle tıbbi tekstil kumaşlarının üretiminde kullanılan alkol itici apre tercih edilmiştir. Genellikle tıbbi tekstilde, tek kullanımlık kumaşlar (non-woven) ve dokuma kumaş tipleri tercih edilir. Bu kumaşlar; hastane kıyafetleri, cerrahi önlükler, maskeler ve örtülerin, tıbbi teknisyenler ve laboratuvar çalışanları için kan veya alkol ile karışık çözeltilerin insan tenine temasını engelleyen koruyucu giysiler elde etmek için üretilmektedir. Günümüzde, tekstil finisaj işlemlerinde pad-dry, kiss-roll, köpük uygulaması ve sprayleme gibi çeşitli yöntemler kullanılmaktadır. Her metodun kendi içinde, istenen aprenin homojen uygulanamaması ve maliyet gibi bazı handikapları bulunmaktadır. Yeni bir yöntem olan electrospray çeşitli kimyasalların aplikesi için uygun bir işlemdir. Bu çalışmada, non-woven ve yıkama dayanımı istenen dokuma kumaşlara 3 farklı yöntem ile (pad-dry- kiss-roll ve electrospray) alkol itici apre uygulaması yapılarak, yöntemlerin performanslarının kıyaslanması ve elektrosprey metodunun kullanım parametrelerinin belirlenmesi hedeflenmiştir. Yöntemlerin performansları AATCC 193-2005 standardına göre kıyaslanmıştır.

Anahtar kelimeler: Elektrosprey, pad-dry, kiss-roll, alkol itici apre, non-woven kumaş

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TABLE OF CONTENTS

	Page
ABSTRACT	v
ÖZET.....	vi
ACKNOWLEDGEMENTS	vii
TABLE OF CONTENTS	viii
Page	viii
LIST OF TABLES	x
Page	x
LIST OF FIGURES	xiii
Page	xiii
CHAPTER 1	1
INTRODUCTION	1
1.1. Introduction	1
1.2. Aim of Study	2
1.3. Structure of the Thesis.....	3
LITERATURE REVIEW.....	4
2.1. Repellent Textile Materials	4
2.1.1. Repellent Finishes	4
2.1.1.1. Mechanisms of Repellency	5
2.1.1.2. Repellent Chemistries for Textile Applications.....	7
Short-chain fluorinated repellent chemistries.....	7
Paraffin repellent chemistries	7
Stearic acid-melamine repellent chemistries	8
Silicone repellent chemistries.....	8
Nano-material based repellent chemistries.....	8
2.2. Application Methods of Finishing Materials	9
Padding	10
Kiss-roll	11

Foam Applicator with Knife.....	12
Spraying.....	13
2.2.1. Electro spraying	14
2.3. Test Methods.....	18
EXPERIMENTAL	20
3.1. Materials	20
3.1.1. Alcohol Repellent Chemicals.....	20
3.1.2. Fabrics.....	21
3.2. Method.....	21
3.2.1. Characterization of Alcohol Repellent Chemicals	21
3.2.1.1. Viscosity of Chemicals	21
3.2.1.2. Conductivity of Chemicals.....	22
3.2.1.3. Surface Tensions of Chemicals	22
3.2.2. Application of Alcohol Repellent Chemicals	22
3.2.2.1. Electro spraying of Alcohol Repellent Chemicals	22
3.2.2.2. Pad-Dry Method of Alcohol Repellent Chemicals	25
3.2.2.3. Kiss-roll application of alcohol repellent chemicals.....	27
3.2.3. Laundering	27
RESULTS AND DISCUSSION	30
4.1. Characterization of alcohol repellent chemicals	30
4.2. Comparison of consumption rate of alcohol repellent materials at processes	33
4.3. Test Results	40
4.3.1. Statistical Analysis.....	47
4.3.1.1. % 100 PES Fabric	47
4.3.1.2. 65/35 Pes/Co Fabric	49
CONCLUSIONS.....	51
5.1 Conclusions	51
REFERENCES.....	53

LIST OF TABLES

	Page
Table.3.1. Experiment Fabric Types	21
Table 3.3.The details of electro spraying process parameters	24
Table.3.3. Drying conditions.....	25
Table 3.4. Parameters of Pad-dry Applications	26
Table.4.1. Viscosity measurements of Alcohol Repellent Chemicals	30
Table.4.2. Conductivity measurements of Alcohol Repellent Chemicals	31
Table.4.3. Surface Tension measurements of Alcohol Repellent Chemicals	32
Table 4.4. Pad-dry method, Chemical A (40gr/lit)	34
Table 4.5.Pad-dry method, Chemical B (40gr/lit).....	34
Table 4.6.Pad-dry method, Chemical C (40gr/lit).....	35
Table 4.7.Kiss-roll method, Chemical A(60gr/lit.)	35
Table 4.8.Kiss-roll method, Chemical B(60 gr/lit.)	36
Table 4.9.Kiss-roll method, Chemical C (60 gr/lit.)	36
Table 4.10.Electrospray parameters.....	37
Table 4.11.Electrospraying method, Chemical A	37
Table 4.12.Electrospraying method, Chemical B	38
Table 4.13.Electrospraying method with Chemical C	38
Table 4.14. AATCC 193-2005 rating factors	40
Table 4.15.Alcohol repellent test results for the woven fabrics at different washing cycles(electrospray method).....	41
Table 4.16.Alcohol repellent test results for the woven fabrics at different washing cycles (pad-dry method).....	42

Table 4.17. Alcohol repellent test results for the woven fabrics at different washing cycles (kiss-roll method).	42
Table 4.18. Alcohol repellent test results for the nonwoven fabrics (Electrospray method).	43
Table 4.19. Alcohol repellent test results for the nonwoven fabrics (Pad-dry method).	43
Table 4.20. Alcohol repellent test results for the nonwoven fabrics (Kiss-roll method).	43
Table 4.21. Electrosprey test results	44
Table 4.22. Pad-dry test results	44
Table 4.23 Kiss-roll test results.....	45
Table 4.21. 1 Wash Cycle alcohol repellency average value for 100% PES fabric according to methods.	47
Table 4.22. 5 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.	47
Table 4.23 10 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.	48
Table 4.24. 15 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.	48
Table 4.25. 25 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.	48
Table 4.26. 1 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.	49
Table 4.27. 5 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.	49
Table 4.28. 10 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.	49

Tablo 4.29. 15 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.	50
Tablo 4.30. 25 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.	50

LIST OF FIGURES

	Page
Figure 2.1 Contact Angle Measurement.	6
Figure 2.2. Single dippadder	10
Figure 2.3. Kiss-roll Application on Fabric	11
Figure 2.4. Foam applicator with knife	12
Figure 2.5. Spraying	13
Figure 2.6. Electro spraying Set-up	15
Figure 2.7. Various modes of electro spraying	16
Figure 2.8. Scheme of electro spray deposition of micro-thin film: from a solution of particles to be deposited	17
Figure 3.1. Electro spraying Unit	23
Figure 3.2. Needles and collector	23
Figure 3.3. Laboratory type padding machine	25
Figure 3.4. Laboratory type of kiss-roll machine	27
Figure 3.5. Laboratory type laundering machine	29

CHAPTER 1

INTRODUCTION

1.1. Introduction

There is a growing interest in protecting human health, especially in the health field. That interest consequently emerged along with a parallel interest over the surgical gowns, as being a side branch of medical textiles. Surgical gowns may be defined briefly as personal protective garments which are designed for acting as physical barriers between sterile and non-sterile zones especially for being able to keep the body from harmful contact away from the health personnel in order to create a safe operation environment and to minimize the risks. The group of surgical clothes is manufactured as disposable and reusable from nonwoven and woven fabrics. Surgical gowns are the most important item among the surgical garments.[29] When applying finishing methods to these garments or fabrics use a lot of techniques on the literature such as kiss roll, pad dry, foaming and spray methods. On the other hand, electrospaying is a new method to apply different finishing materials to fabrics[1].

Electrospaying provides a new routes to nanotechnology. This method can be used for particle production, capsule formation size in micro or nano and thin- film deposition. Thin films are used in medical technology, microelectronics, and modern material technologies. Studies are aimed at developing in cosmetics, medicine production, ingredients dosage in food industries and new drug delivery systems. Electrospinning make possible the manufacturing of nanofibers for scaffolds for biological tissue, filters, masks and intelligent garment manufacturing[2].

Electrospray is a method of generating liquid atomization with electrical forces. In electrospray, liquid passes through the nozzle, the charged liquid in the nozzle becomes unstable as it is forced to hold more charge. Soon liquid can keep a much

electrical load which reaches a critical point. Then static electric force splits the liquid into the charged droplets. The droplet size depends on a lot of parameters such as applied electrical charge, surface tension of finishing materials, distance of collector to nozzle head, viscosity, conductivity and the others [1,2]. Consequently, those small droplets cover the surface of the fabric as a thin film.

Nonwoven fabric finishing providing a barrier to liquid penetration for the fabrics which are suitable as surgeon's gowns, medical drapes, isolation gowns and the like. The finish serves to minimum amount of microbial contamination to the fabrics. [3]. For wet finishing application to the fabric has many methods, electro spray which is the new, easy, simple and the cheapest method because of less finishing material consumption[4].

1.2. Aim of Study

The purpose of this thesis is to practically compare the advantages and disadvantages of the most commonly used kiss roll and pad dray methods with the electro spray method using alcohol repellent finishing materials. Electro spraying is a new, easy and less expensive method of wet finishing application. Additionally, electro spray is environmentally friendly since chemical material will not be wasted at the end of the process. However, the common finishing methods usually discharge some amount of waste chemical materials to the environment. Also, the novelty of the study is that alcohol repellent finishing is not a common finishing method. Therefore, the literature does not comprise too many studies about know-how of alcohol repellent application.

The first step of the study is to determine the electro spraying parameters for alcohol repellent finishing materials to apply them for nonwoven and woven fabrics. The optimal values of the process (applied voltage, tip collector distance and flow rate) and solution parameters (concentrations and conductivity) were determined practically (by trial and error) to obtain the best performance from the electro spray process. Two nonwoven fabrics with different weight in grams and two woven

fabrics were used for electrospraying of alcohol repellent finishing applications. The second step of the study is the application of the finishing process. Three different alcohol repellent chemical finishing materials were used in the experiments. Same amount of alcohol repellent materials were applied to the fabrics in order to compare the performances of all three finishing process (kiss-roll pad-dry and electrospray methods). Finally, the drying and fixing processes were applied to the all samples in order to complete the procedure. Washing operations were applied to the samples as 1,5,10,15 and 25 home launderings to determine washing resistance of each method. Finally, alcohol repellency tests were applied to each sample to analyze the results.

Experimental results show that the electrospray method can provide good performance as much as pad-dry and kiss roll finishing methods. Additionally, the method reduces the cost of process considerable with respect to the other methods, because of less heat energy requirement for drying and fixing process. Moreover, the electrospray method is healthier than pad-dry method since it can cover single side of fabrics.

1.3. Structure of the Thesis

The general definition about electrospraying method is given in Chapter 2. Beside, the method is defined and its importance is emphasized. The details of alcohol repellent finish types and their different application processes (there is no too much studies in the literature) were explained. Additionally, the details of electrospraying, are given in chapter 2 also. In Chapter 3, the materials and methods are presented. The sample fabric parameters, alcohol repellent finishing material types and their specialties, treatment processes, fabric specimen preparation were explained in detailed form. Chapter 4 covers the results of the all test according to alcohol repellent test standard of “AATCC 193-2005;Aqueous Liquid Repellency: Water/Alcohol Solution Resistance Test and discussions of these results. In chapter 5, the conclusions of this study and recommendations for further studies were presented.

CHAPTER 2

LITERATURE REVIEW

The marketplace for textile products which consist of functional textile is consistently raising with an increasing interest the manufacture of nonwoven fabrics and their treatment to impart desired properties. More particularly, it relates to such fabrics that are desired for applications requiring alcohol repellency. Applications for fabrics with these properties include, but are not limited to, disposable items for surgical room use such as gowns, drapes, table covers and the like. A particular application is in the manufacture of textile products to enclose items to be woven types and maintain them in a sterilized condition until used. Such nonwovens are manufactured from a wide variety of materials including naturally hydrophobic fibers of synthetic polymers such as polypropylenes, polyolefins, polyesters, polyamides and the like. In this manner, economy of production as well as product improvements may be obtained [7]. There are numerous kinds of alcohol repellent finishes that can be used with different methods for textile materials.

2.1. Repellent Textile Materials

Surgical drapes, hospital gowns, wrap instruments and like materials are typically made of non-woven textile. When such flourocarbons are applied to a non-woven substrate it was found that the substrate was rendered partially hydrophobic, they have tobe sufficient to repel body fluids, alcohol and like liquids typically present in a hospital environment [10].

2.1.1. Repellent Finishes

Chemical finishing has always been an important component of textile processing, but in recent years the trend to 'high tech' products has increased the interest and use

of chemical finishes. As the use of high performance textiles has grown, the need for chemical finishes to provide the fabric properties required in these special applications has grown accordingly. In terms of value, the repellent group is the leader with the highest ratio of cost per amount. This reflects the relatively high cost of the fluorochemical subgroup of repellents[8].

Finishes that repellency of water, oil and dry dirt or alcohol repellency are important in all parts of the textile market for clothing, home, medical textiles. These are modified to have a wide range of properties to fit the different demands of the users and the intended purpose. This is one of the most interesting new developments of chemical finishing[11].

2.1.1.1. Mechanisms of Repellency

Repellent finishes achieve their properties by reducing the free energy at fiber surfaces. If the adhesive interactions between a fiber and a drop of liquid placed on the fiber are greater than the internal cohesive interactions within the liquid, the drop will spread. If the adhesive interactions between the fiber and the liquid are less than the internal cohesive interactions within the liquid, the drop will not spread. Surfaces which exhibit low interactions with liquids are referred to as low energy surfaces. Their critical surface energy or surface tension must be lower than the surface tension of the liquid that is repelled. There are different ways that low energy surfaces can be applied to textiles. The first way is mechanical incorporation of the repellent products in or on the fiber and fabric surface, in the fiber pores and in the spacing between the fibers and the yarns. Another approach is the chemical reaction of the repellent material with the fiber surface. Another method is the formation of a repellent film on the fiber surface. Examples of these are silicone and fluorocarbon products[8].

When measuring the repellency of a textile, it is important to maintain differentiation of the terms: Repellency and contact angle. Repellency describes how well a fabric resists the absorption, adsorption, and penetration of water on a fabric surface. The

measurement of the contact angle of a liquid on the surface of a fabric is a method of quantitatively describing the surface energy of the substrate[14].

The contact angle of a liquid on the surface of a material is an indirect measurement of the wettability, and directly relates to the interactions of the solid, liquid, and gas phases. Thus, the differences between the surface energies of the solid-vapour and solid-liquid phases strongly affect the resultant contact angle formed between the solid and liquid. It should be noted that Young's Equation is based upon a perfect system where the solid surface is smooth and homogeneous. The contact angle of a droplet on a substrate is the angle formed between the solid-liquid interface and the liquid-vapour interface, and is shown in Figure.2.1[15].

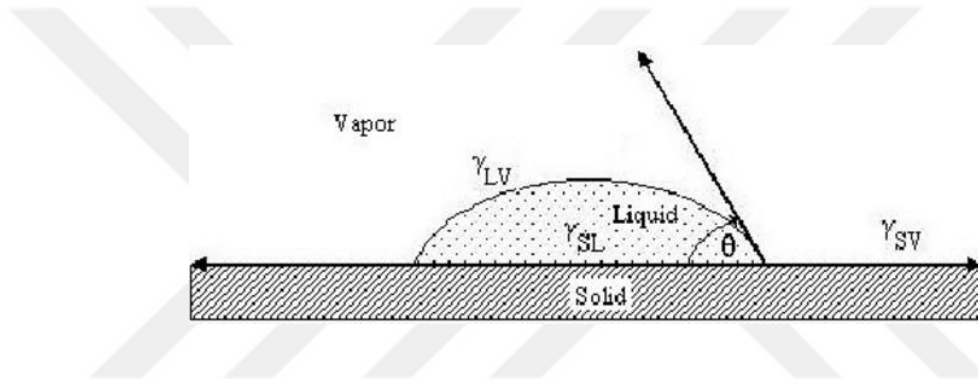


Figure 2.1. Contact Angle Measurement[15]

When $\theta \leq 90^\circ$, the surface is said to be hydrophilic and the drop wets the surface. If the contact angle is 0° , then the solid-liquid interaction is greater than or equal to that of the liquid-liquid interaction. Conversely, if the contact angle is 180° , then there is no interaction between the solid and liquid phases. When the contact angle exceeds 90° , wetting of the substrate does not occur, and the substrate is said to be hydrophobic. In this case, the interaction between the liquid and gas phases is greater than the interaction between the solid and liquid phases. When surfaces have contact angles greater than 90° , the fluid and surface are unable to efficiently form secondary bonds. Increasing surface roughness has also been shown to positively impact the water repellency of smooth surfaces[16-17].

2.1.1.2. Repellent Chemistries for Textile Applications

Short-chain fluorinated repellent chemistries

There is some worries about related with long-chain perfluoroalkyl acids (PFAA),so a shift towards durable water repellents chemistries with shorter perfluoroalkyl chains (also showed “C6” or “C4” which depending on the number of carbons in the perfluoroalkyl chain). Chemically, short-chain fluorinated chemistries are closely related to their long-chains homologues. Durable repellents containing short-chain fluorinated chemistries are produced using perfluoroalkyl raw materials such as fluorotelomer alcohols that are not expected to break down in the environment into perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonic acid(PFOS)[24].

Short-chain per fluorinated repellency chemicals, as having comparable repellency and other performance attributes to long-chain chemistries, are encouraged now by the chemical industry. In general, short-chain fluorinated DWR chemistries are not as effective as those with long-chain chemistries, particularly in repelling oil. The claim that short-chain fluorinated chemistries are substitutes for DWR finishes with long chain chemistries may not necessarily imply a simple replacement of currently used DWR finishes. Substituting a long-chain with short-chain fluorinated DWR chemistries may require optimizing application methods[25].

Paraffin repellent chemistries

Paraffin was one of the earliest water repellent chemistries used. These repellent products are generally emulsions containing aluminum or zirconium salts of fatty acids, usually stearic acid. They provide good water repellency due to their zirconium ion holding onto fiber, and the fact that their water repellent groups have good orientation on fiber surfaces. Despite providing good water repellency effects, paraffin repellents do not repel oil and are generally not durable to laundering and dry cleaning[8].

Stearic acid-melamine repellent chemistries

These type repellent chemistries are formed by a reaction between stearic acid and formaldehyde and melamine. The hydrophobic character of the stearic acid groups provide the water repellency, while the N-methylol groups that are formed react with cellulose or with each other to generate permanent repellent effects. This methods advantage is that they have increased cycles of laundering. However, these type repellents have decreased abrasion resistance and fabric tear strength, this changes the effects of dyed fabrics and release formaldehyde. The release of formaldehyde is a problem for human health and safety given the adverse effects from exposure. Formaldehyde is classified as a known human carcinogen[26].

Silicone repellent chemistries

Polydimethylsiloxanes are the most common silicone repellents. Their unique chemical type ensures the ability to form hydrogen bonds with fibers, indicates the repellent effects on textile materials. Silicones to gain durability of repellent consist of a silanol, a silane and a catalyst such as tin octoate. With silicon repellents obtains a high degree of water repellency at low concentrations. The disadvantages of silicone repellents include increased pilling and seam slippage of textile materials, and also decreases repellency if excessive amounts are applied. These type repellent materials have only reasonable level of durability to laundering and dry cleaning, and they have no oil and soil repellency. After used silicone repellents on finish application processes, the waste water of solutions, is toxic.

Nano-material based repellent chemistries

Nano-material based repellent chemistries used to get the desired properties on fabric weight , thickness and hardness on textile materials without a significant increase. These specialties on textiles using nanotechnology include water repellency and soil

resistance. The use of nano-materials to serve water repellency and stain resistance effects on textile material is one of the most common ways nanotechnology is being used in the textile industry. To obtain specialties, and also this type of repellent materials is to try to get maximum home laundering cycles[27]. To avoid damaging to environment and also to human, the knowledge is limited about assessment available of nano-materials. These knowledge all about suggests that nano-materials have toxic properties to both human health and the environment, these nano-particles may have greater risk than larger particle. Unlike larger particles, nano-materials are capable of being transported within human cells and be taken up by cellular structures and cause cell damage due to their greater chemical reactivity[28].

2.2. Application Methods of Finishing Materials

Differ from preparation or dyeing operation in the manufacture of textiles need to improve the appearance or imparts useful characteristics to the fabric and also the fabric multiple uses for market versatility. In fact, some processes that are usually classified as preparation steps can also be done as finishing steps. Finishing steps are generally done after the fabric has been dyed, so the effect of finishing on the final fabric shade must be taken into account [8].

The various classifications of chemical finishes are that improve softness, water oil repellency, flame resistance or alcohol repellent are available, but the general procedure for applying any chemical finish is to expose the fabric to a solution, generally aqueous, of the active chemical followed by uniform drying to remove the solvent and then curing of the active chemical by exposure to high temperatures. During the curing step, a chemical reaction is usually taking place. This reaction can bind the finishing chemical to the fabric or bind it to itself to form a network structure that promotes durability of the finish[9].

Padders, or squeeze rolls, are often used to apply chemicals to fabric. A lower, more efficient use of water in the chemical application procedure can be achieved with

various application methods, including kiss roll applicators, foam application and sprayers[9].

Padding

In padding, the fabric passes through a trough containing the finishing solution and then through squeeze rolls to remove excess solution before going to drying and curing.

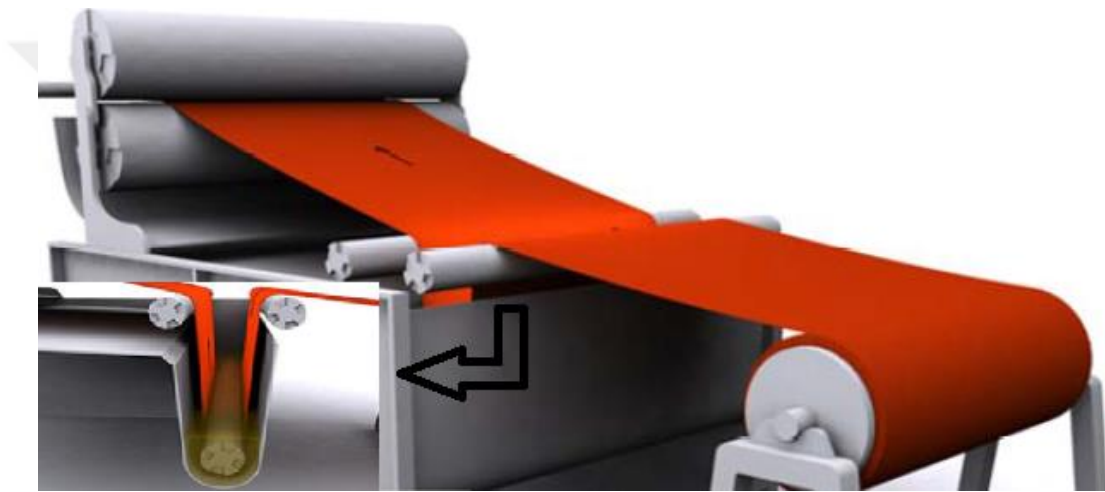


Figure 2.2. Single nip padder[8]

This is a side view of a single dip on **Figure.2.2**, single nip padder configuration, which is the most common type. The “dip” refers to immersion of the fabric in a trough or pan containing the finishing chemical solution, and the “nip” refers to the point of contact of the fabric between the two squeeze rolls. The squeeze rolls are sometimes called a mangle. One of the rolls can be rubber and the other metal, and the pressure between the rolls determines percent wet pick-up. Percent wet pick-up can also be influenced by fabric construction and the nature of the fiber itself. Percent wet pick-up is defined as the weight of liquid picked up by the fabric after padding expressed as a percentage of the original dry fabric weight. If the pressure

on the squeeze rolls is too low, the solution can puddle up on the fabric, resulting in uneven drying and migration of the finish. It may be possible to save water and drying costs by increasing the concentration of active chemicals in the pad bath, thus requiring a lower value for wet pick-up, but doing so decreases the likelihood of uniform coverage over the fabric. Thus, the proper settings are a balancing act between energy efficiency and product quality[8].

Kiss-roll

This is a method for applying finish to one side only of a fabric. In this method, the kiss roll revolves through the chemical bath and transfers the finishing chemicals to the fabric as it passes across the top of the roll shows on **Figure.2.3.**

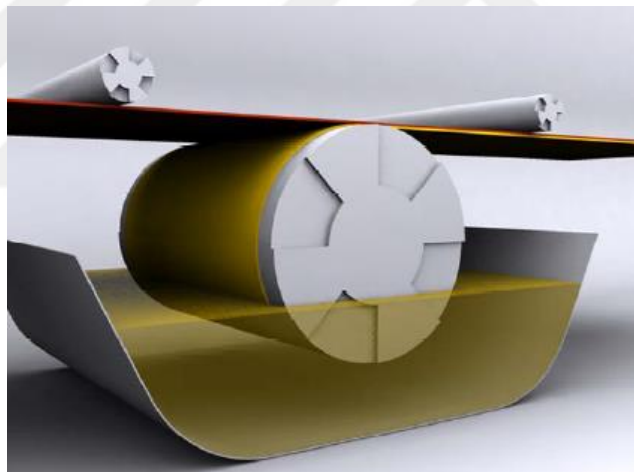


Figure 2.3. Kiss-roll Application on Fabric[8]

The fabric is not ever immersed in the bath. The wet pick-up on the fabric is determined by the speed of roller rotation, the speed of the moving fabric and the viscosity of the solution. Two small guide rolls on the top side of the fabric hold it against the kiss roll, which is rotating in the same direction that the fabric is moving. A typical use for the kiss roll is mostly used method for alcohol repellent finishing

treatments for non-woven fabrics, however this methods may have not apply the finishing material homogeneously to the fabric surface. The amount of finish applied cannot be precisely controlled by the kiss roll applicator, but the method is suitable for finishes that are not very costly and are desired on only one side of the fabric[12].

Foam Applicator with Knife

Applying chemical finishes to textiles by minimizing water consumption is by using foam rather than liquid to deliver the active chemicals. Foam is a collection of air bubbles created by beating or whipping a liquid, and it can, therefore, be considered as a liquid diluted by air. Application method is given **Figure.2.4.** [8]

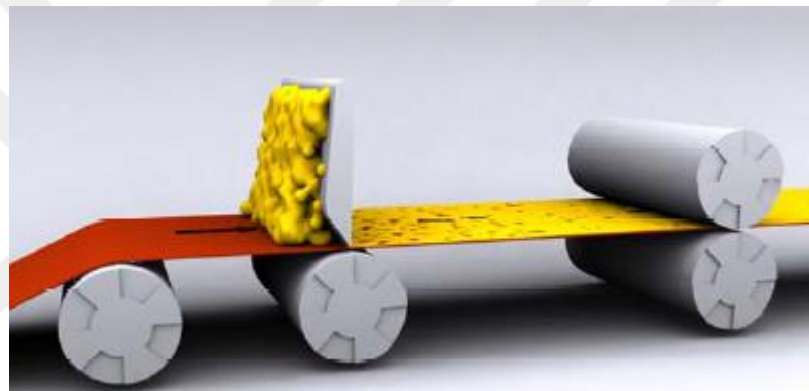


Figure 2.4. Foam applicator with knife

Pure water does not foam unless a surfactant, or foaming agent, is added. The density of the foam can be described by a number called the blow ratio, which is the ratio of the volume of foam to the volume of the original liquid. Lower density foams (higher blow ratio) have larger bubbles than higher density foams. The stability of the foam is dependent on the strength of the liquid walls of the bubbles. Foam stability is described by the term persistence, which is defined as the time it takes foam to revert back to a liquid. Foam persistence can be increased by adding a thickener or a water-soluble polymer that will increase the viscosity of the liquid. Foams for textile finishing applications can be categorized, depending on their stability, as either persistent or semi stable. The foam must therefore be stable with a low tendency to

evaporate. The add-on of foam is controlled by the distance, or gap, between the knife blade and the fabric surface. After metering of the foam by the knife, the fabric passes between squeeze rolls or a vacuum slot to break the bubbles in the foam and cause penetration of the liquid into the fabric [8]. Foam applicator method is not suitable for alcohol repellent materials, because repellent materials have high viscosity and also not recommended to convert form to foam by their producers.

Spraying

A sprayer is another way to apply chemical finishes by using lower amounts of water than conventional padding, provided that the chemical mix is compatible with this type of application and does not lead to clogging or blockage of the nozzles. The **Figure.2.5.**[12] shows two rows of nozzles spraying finish across the width of the fabric, one row for each side of the fabric. The machinery can be configured to spray one or both sides of the fabric.

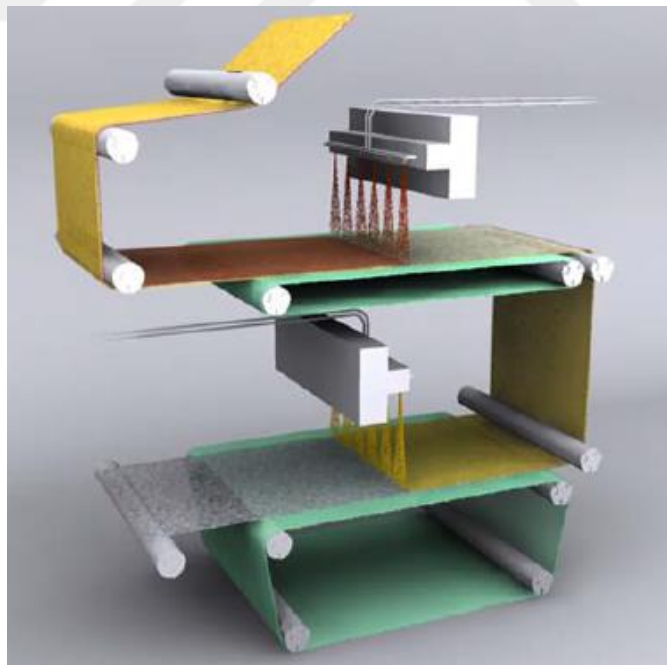


Figure 2.5. Spraying

The nozzles and the spray streams are spaced across the fabric so as to give uniform, complete coverage of the fabric surface without an overlap of the streams, which would result in a double application of the finish. For one-sided applications of finish to fabric, the penetration of the solution depends on the amount of solution applied, or wet pick-up, and the absorptive nature of the fiber. Cotton fabrics would absorb the solution into the fibers, thereby minimizing migration to the other side of the fabric. For polyester or other hydrophobic fibers, the finish would not be absorbed and would penetrate through the fabric by capillary action. For a cotton fabric, a wet pick-up of at least 40% would be needed in order for the finish to completely penetrate the fabric. In cases where it is desirable to concentrate the finish on one side of the fabric, a lower wet pick-up could be utilized [8,12].

2.2.1. Electrospinning

This method has been used to provide one-dimensional materials relatively recently, but the idea was first recommended over 100 years ago[22]. The earliest found to date of electrospinning, Cooley patented a setup that used auxiliary electrodes to direct the electrospinning jet onto a rotating collector in 1902[23]. Electrospinning is a method of generating liquid atomization with electrical forces. The name of electrospinning is used for an equipment that uses electricity power to disperse a liquid or for the fine aerosol resulting from this process. The method is occasionally called electro hydrodynamic atomization. High voltage is applied to a liquid which is supplied through an emitter which is a glass or metallic capillary. Optimally the liquid reaches the emitter tip in the form a Taylor cone, which emits a liquid jet through its apex. In electrospinning, a liquid is passing through the nozzle. The charged liquid in the nozzle becomes unstable as it is forced to hold more and more charge. Soon liquid can keep a much electrical load which reaches a critical point. The nozzle head has highly charged droplets. The droplet size depends on a lot of parameters such as applied electrical charge, surface tension of finishing materials, distance of collector to nozzle head, viscosity, conductivity and the others [1,2]. The charged droplets accelerate through the collector surface. Thus, the surface of any

object between the nozzle and collector would be covered with atomized solution. The set of electrospray is showed on **Figure 2.6**.

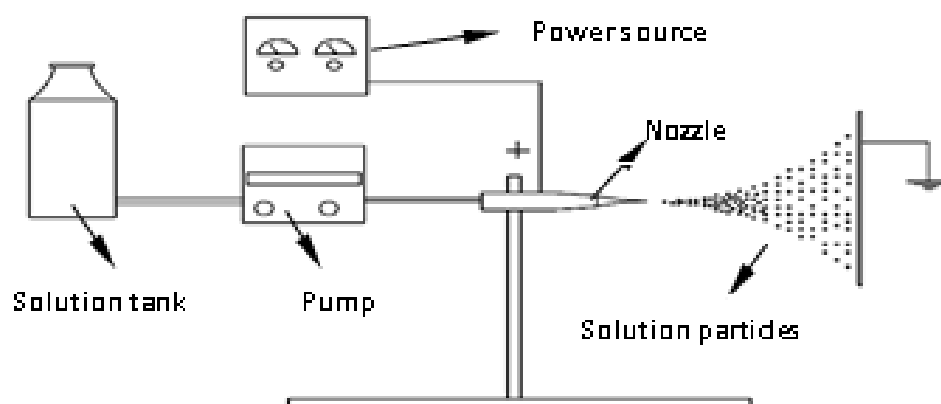


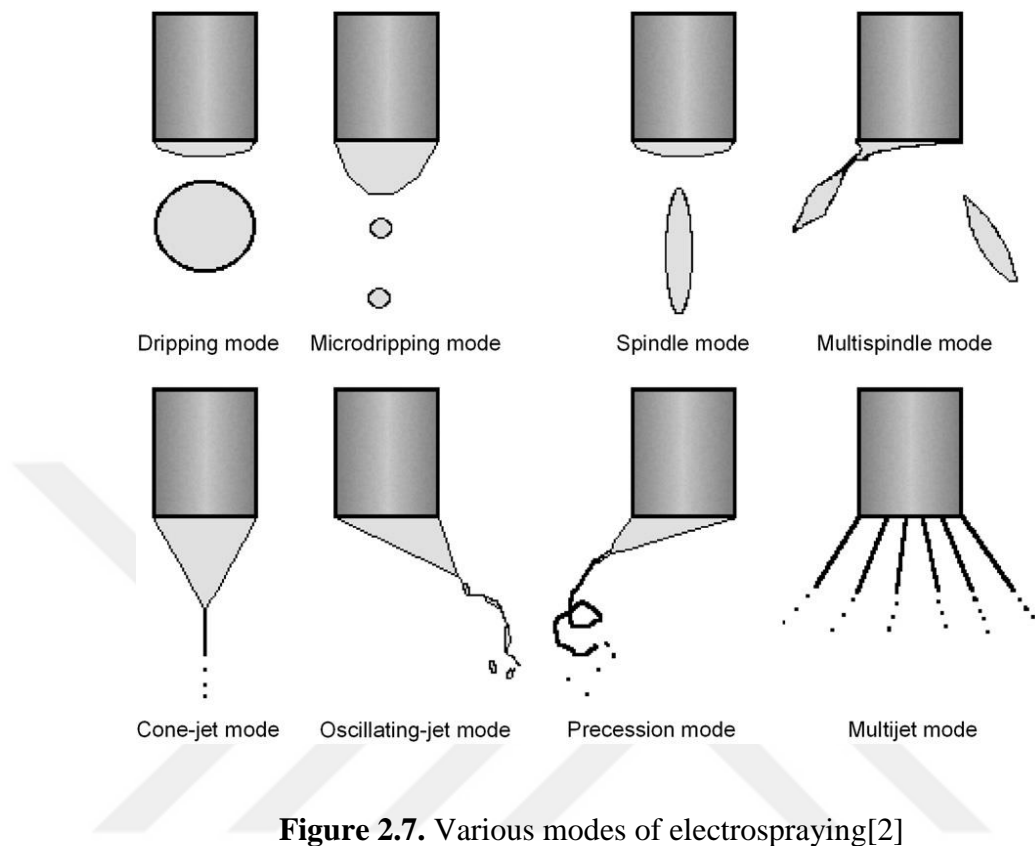
Figure 2.6. Electro spraying Set-up

Fork-shaped waves on the surface of the liquid jet result in the formation of highly charged and small liquid droplets dispersed by Coulomb repulsion. Electro spray setup can be cheap and simple. A polymer solution is loaded into a conductive nozzle of a syringe and ejected at a desired rate generally applied by a syringe pump. A high voltage is applied to the nozzle and various types of collectors (often grounded or rather negatively charged) are placed at a desired distance [1].

The size of these tiny droplets are less than $10\ \mu\text{m}$ and fly to find a potential surface also the fabric on collector to land on that is opposite in charge to their own. When they fly, they quickly reduced due to solvent molecules evaporate from their surface. If the droplets cannot find a place to discharge in time, the electrical charges reaches a critical state and the droplet will promptly blow apart again[18].

Numerous forms of spraying are distributed in the literature, depending on the pattern of displacement of the beam, the shape of the meniscus and in such a way that it disintegrates into droplets. Several forms of the electro spray method are shown schematically in Figure 2.7.[2] Cone-jet mode is the primary injection mode. In this mode, the liquid meniscus takes the form of a regular cone of axial symmetry with a

thin beam at its apex extending along the axis of the capillary. The end of the beam is an exposed instabilities of two types: kink and varicose [2].



Until this time, many researchers have tested the electro spray deposition technique of liquid-phase materials on many substrates. Objected to a substrate to form a tight surface layer are formed with electro spray deposition (Figure.2.8)[2], is a process in which droplets produced by electro spraying from a solution of a material. An active substance layer is obtained after solvent evaporated. Usually, the material is sprayed directly onto the substrate, but the layer can also be formed from an active substance[2].

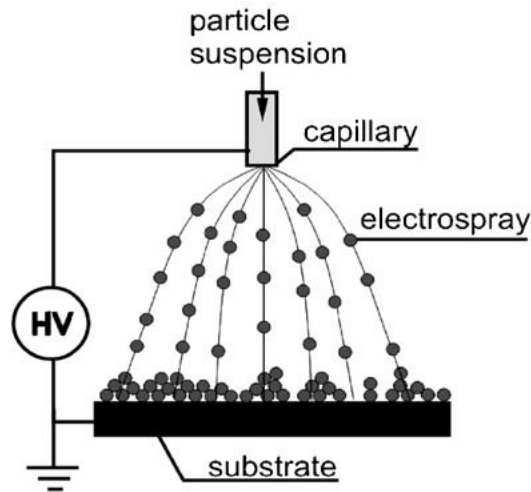


Figure 2.8. Scheme of electro-spray deposition of micro-thin film: from a solution of particles to be deposited [2]

The researchers are interested in the use of this method and report that the films produced by electro-spray are homogeneous and composed of small agglomerates consisting of particles smaller than $1\ \mu\text{m}$, particles of active substances used for the preparation of crystallites less than $1\ \mu\text{m}$. The crystallites are formed as they leak to the substrate. In specific cases, the layer has better properties than those obtained by other methods. The spraying systems used generally operate in cone-jet mode, but sometimes the multi-jet mode is also used [19, 20].

Electrospraying method compared with other techniques, electro-spray technique has produces highly-charged with ability to non-agglomerated, and the particles obtained in a wide size range from the nanometer to micrometer. The electro-sprayed materials have incomparable properties supply more controlled on the deposition and dispersion of particles. Some features of technology improve many biological and medical applications where the morphology, precise control of particle size, and electrical charges related to the control on the particle deposition and dispersion are needed[21].

2.3. Test Methods

Test methods for the most part in textile to evaluate the textile materials of performance properties after finishing agents applied on fabric such as they developed by the American Association of Textile Chemists and Colorists (AATCC), International Organization for Standardization (ISO) and the American Society for Testing and Materials (ASTM). The most widely used test methods in the textile industry are that the AATCC standardized test methods. AATCC test methods results and test methods from other organizations are numerically quantified which is the most important point of standardization organizations. The following method is the widely used test methods for fabrics treated with an alcohol repellent finishing. AATCC TM 193-2005 refers to aqueous liquid repellency: water/alcohol solution resistance test. This test method provides and determines the efficacy of finishing materials on finished materials and evaluating the resistance to wetting of textile materials, so the drops of a selected series of water/alcohol solutions of different surface tensions are placed on a treated fabric surface and observed for wetting. This test method is used to evaluate the effectiveness of the finish in imparting a low surface energy on the surface of the treated fabric.

The finished textile materials resistant to alcohol may find a place in the global textile market, in medical textiles. Medical textiles are textiles and building products for medical applications. Examples of their use are the textile protection and medical care, dressings, surgeon gowns, medical tents, hygiene products, clothing insulation and the like. Final applications can be designed to meet the needs of many people and their profession. These types of requirements usually performed to the medical industry. The level of these types of surfaces, clothing and medical supplies is steadily growing. Textiles for many purposes in the halls of the basic features and controls used to protect patients personnel to avoid hygiene in order to ensure the infection of the wound, the patient, the surgeon, the surgeon, which is to reduce, to move the risk of patient infection. For this purpose, the use in the operating room materials must have certain criteria.

In this study, three different methods were practiced for finishing application to textile materials. Although there are plenty of studies about the padding and kiss-roll application, but there are very limited studies about the use of the electrospray method for finishing application in the literature.



CHAPTER 3

EXPERIMENTAL

This chapter deals with the materials used, finishing methods and test method. The material part related with alcohol-repellent chemicals produced by different companies. Nonwoven and woven fabrics in different structures were used as a textile surface for finishing application. Lastly, three different finishing methods, kiss-roll, pad-dry and electrospray were used in the experimental study. In addition, sequential washing process was applied to examine washing resistances of samples. The details of test method for alcohol repellent chemicals are explained Chapter 4.

The study aims to compare the results of electrospray finishing method with the conventional pad-dry and kiss-roll methods using alcohol repellent finishing. Therefore, alcohol-repellent finishing materials were applied to nonwoven and woven fabrics by all those three methods. Then sequential washing tests were applied to the fabrics obtained. Finally, the results were analyzed by regarding the washing resistance of sample fabrics obtained from each finishing method.

3.1. Materials

3.1.1. Alcohol Repellent Chemicals

Although there are different alcohol repellent finishing materials three of them including Repellan EPF (by Pulcra Chemicals), Rucostar EEE (by Rudolf Duraner Inc) and Tubiguard 10F (by CHT Chemical Inc) were used for the experimental study.

3.1.2. Fabrics

The fabrics used in the study were chosen among the fabrics widely used in the medical sector. Nonwoven fabrics are supplied from 3Teks (Gaziantep) which produces medical textile products. These fabrics are usually used for surgical sheets, surgical gowns and also laboratory coats. These fabric types have wide range of uses and they are disposable. The woven fabrics used in the experimental work were obtained from Oğuz Tekstil (Adana). These fabrics were used at the front of the surgical gowns and also at the front of the arm section of gowns to make them re-usable. In order for these fabrics to be re-usable again, it is necessary to have washing resistance of alcohol repellent chemicals. The properties of fabric to be used in the experiment study are given in Table 3.1.

Table.3.1. Experiment Fabric Types

Experiment Fabric Specimens		Weight in grams – Woven types	Types
Non-wovens	1	35 gr/m ²	Disposable
	2	45gr/m ²	Disposable
Woven Fabrics	1	%100 PES -Plain	Re-Usable
	2	%65 Co %35 PES - Plain	Re-Usable

3.2. Method

3.2.1. Characterization of Alcohol Repellent Chemicals

In order to characterize the prepared solutions, viscosity, conductivity and surface tension measurements were taken before application.

3.2.1.1. Viscosity of Chemicals

Chemicals viscosities were analyzed according to Brookfield Viscosity Standard with using Brookfield DV III Ultra Programmable Rheometer device. Measurements of viscosity were taken for 200 rpm with using spindle number 27 at 20⁰C. Measurements were repeated in 3 times and their averages were calculated, which the results are showed at chapter 4.

3.2.1.2. Conductivity of Chemicals

Measurements obtained by Orion 4 Star Plus pH meter device at 20⁰C. Chemicals diluted with distilled water, forwhy to obtain optimum conductivity ratio for electro spraying. Measurements were repeated in three times and their averages were calculated. These measurements results showed at chapter 4.

3.2.1.3.Surface Tensions of Chemicals

Surface Tension values of Chemical measurements were obtained by KSV Theta Optical Tensiometer. Chemicals diluted with distilled water, forwhy to obtain optimum surface tension ratio for electro spraying. Measurements were repeated in 3 times and their averages were calculated.

3.2.2. Application of Alcohol Repellent Chemicals

The finishing application methods (electro spraying, kiss roll and pad-dry) and drying/fixing conditions and also laundering process will be described below.

3.2.2.1. Electro spraying of Alcohol Repellent Chemicals

The electro spray assembly consists of two (plus and minus) 0-50 kV ES50P Model Gamma high voltage power supply, New Era NE-1000X pump and rotatable cylindrical collector. There is also a humidity generator, a dehumidifier, heater and a cooler units to control temperature and humidity inside the cabinet (see Figure 3.1). The set up was produced for a Scientific Research Project in Gaziantep University. In order to transfer the chemical material to the fabric texture, multiple jets were used and the collector was rotated at 30 rpm. In addition, homogeneous dispersion is achieved by providing forward and backward movement of the jets mounted on the slider. Alcohol repellent chemical material was applied to the single surface of the fabric by this electro spray procedure.



Figure 3.1. Electrospinning Unit



Figure 3.2. Needles and collector

First, each fabric (woven and non-woven fabric) was cut into rectangles of dimensions 16x30 cm to cover the collector surface. The alcohol propellant was diluted 1:16 (diluent / distilled water) with distilled water to save finishing material

and obtain a homogeneous chemical distribution on the fabric surface. Then the finishing solution was pumped into jets (6 jets) by means of a syringe pump. Then, electro spray process was started by application of high DC voltage to all jets. Due to the electrostatic force, the chemical and finishing solution reduced to micro and nano size was transferred to the fabric surface placed on the rotating collector. (Figure 3.2.) Details of the process parameters are given in Table 3.3. Chemical application quantities are also given in Chapter 4.

Table 3.3.The details of electro spraying process parameters

Alcohol Repellent Materials	Voltage (kV)	Distance (cm)	Degree (C°)
Chemical A	(+)35, (-) 15	7	25
Chemical B	(+)30, (-)10	7	25
Chemical C	(+)30, (-)10	7	25

Subsequently, the treated nonwoven samples were dried up at 110°C temperature with 90 seconds in the oven. Similarly, the treated woven samples were mounted on pin frames of stenter, dried up at 130°C temperature with 120 seconds in the oven. Finally systematic laundering process (the conditions given in Table 3.3) according to “AATCC 193-2005; Aqueous Liquid Repellency: Water/Alcohol Solution Resistance Test” standard were performed to the treated samples.

Table.3.3. Drying conditions

Alcohol Repellent Materials	Fixed	
	Non-woven(°C/sec)	Woven(°C/sec)
Chemical A	110/90	130/120
Chemical B	110/90	130/120
Chemical C	110/90	130/120

3.2.2.2. Pad-Dry Method of Alcohol Repellent Chemicals

Alcohol repellent chemicals application of pad-dry method was performed by a laboratory type padding machine at Gaziantep University Laboratory (Figure 3.3).



Figure 3.3. Laboratory Type Padding Machine

In experimental work, the finishing materials were applied in accordance with the prescription suggested by the manufacturers. These recommended guidelines are shown in **Table 3.4**.

Table 3.4. Parameters of Pad-dry Applications

Materials	Concentration (g.l ⁻¹)	pH	Velocity (m.dk ⁻¹)	Pressure of rolls (bar)	Fixed	
					Non- woven (°C/sec)	Woven (°C/sec)
Chemical A	40	4,5 – 5	3	2	110/90	150/120
Chemical B	40	4,5 - 5	3	2	110/90	150/120
Chemical C	40	4,5 - 5	3	2	110/90	150/120

The amount of fluid absorbed by the fabric was calculated by regarding the weight measurements before and after application of the alcohol repellent solution. Using the difference obtained, the consumption rate is calculated. These calculations have been applied to fabrics which have been applied with finishing by the entire pad-dry method. The calculation results obtained are shown in Chapter 4. A short summary of the method of application; the fabrics were cut into 16 cm x 30 cm dimensions and the chemical solutions was prepared with the recommended concentrations to immerse these fabrics. Then woven fabric specimens were mounted on the needles of the oven then these fabrics were dried at 150° C for two minutes. On the other hand, nonwoven fabrics were again mounted on the pins of the clippers and dried at 110°C for 90 seconds. Subsequently, woven sample fabrics were subjected to sequential washing tests and left to dry on their own. After the drying process, alcohol repellency tests were applied to all the sample fabrics.

3.2.2.3. Kiss-roll application of alcohol repellent chemicals

The kiss roll method was used in this study since it is the preferred method of applying finishing to nonwoven fabrics. In this method, there are two rollers in the assembly. The first roller surface is grounded. The second roller is located on the first roller and its surface is covered with rubber. As the fabric passes between the rollers, the steel roller, some of which comes into contact with the finishing solvent in the vessel, takes some finishing material and transfers it to the fabric surface. The amount of finishing chemical transferred depends on the rotational speed of the rollers, on speed of the fabric and on the solution viscosity. The most important disadvantage of this method is that the distribution of the finishing material may not homogeneous because the pressure between the rollers is not equal at every point. This method was carried out in laboratory-type machine in ACN chemical company (Adana). (Figure 3.4).



Figure 3.4. Laboratory type of kiss-roll machine

A typical use for the kiss-roll is the application of one side to the fabrics. The calculations of the consumption of chemicals showed in chapter 4.

3.2.3. Laundering

The woven fabrics which were treated by alcohol repellent chemicals (by electro spraying, kiss-roll and pad-dry methods) were washed based on ISO 105 C06-

A2S with 1, 5, 10, 15 and 25 laundering cycles. A laboratory type washing fastness machine (Figure 3.5.) was used and the samples were dried up at ambient conditions (totally 72 specimens). The independent variables are fabric types (woven fabrics; %100 Cotton and %65/35 Cotton PES Fabrics), chemical finishing material types (i.e. Chemical A, B, C) and the laundering cycles (i.e., 0, 1, 5, 10, 25). The laundering procedure steps were as followed:

- 1) Each finished samples was cut into 5 rectangles measuring 100 mm x 40 mm and their all edges were sewed to avoid of fringing.
- 2) The wash liquor was prepared by dissolving 4 g/lit of detergent and 1 g/lit of sodium perborate with water.
- 3) The washing solution was heated up to 40 °C.
- 4) 120 ml of wash liquor was added to each stainless steel container and then the specimens were placed in the container together with ten steel balls. The container was closed and the machine was operated at 40 °C and 30 minutes. This process was accepted as 1 washing cycle. If the machine is operated at 40 °C in 45 minutes, process is accepted as 5 washing cycle. Each specified washing cycles (i.e., for 10 washing cycles operated at 40 °C in 45 minutes two times and also 25 washing cycles operated for same conditions five times) were performed.
- 5) The specimens were removed at the end of the wash. They were rinsed twice for 1 min in two separate 100 ml portions of water at 40 °C.
- 6) Lastly, the specimens were dried up at ambient conditions.



Figure 3.5. Laboratory type laundering machine

CHAPTER 4

RESULTS AND DISCUSSION

This section contains a comparison of the results of alcohol-repellent applications performed with three different methods (electrospray, kiss-roll and pad-dry).

4.1. Characterization of alcohol repellent chemicals

Chemical materials were diluted with distilled water at $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{8}$ and $\frac{1}{16}$ ratios in order to prepare solutions of three different alcohol repellent substances (Chemical A, B and C) in the first stage. These dilution ratios were obtained from some preliminary studies. Measurements of viscosity, conductivity and surface tension of these solutions were also made for electro spray application. The results of the viscosity measurements of alcohol-impelling chemicals are given in Table 4.1.

Table.4.1. Viscosity measurements of Alcohol Repellent Chemicals

Viscosity values of Chemicals	Conditions; Spindle: 27, 200Rpm			Averages
Measurements	1	2	3	
Chemical C	2,5	2,54	2,68	2,57
Chemical C (1/16)	1,23	1,21	1,23	1,22
Chemical B	6,24	6,27	6,24	6,25
Chemical B (1/16)	1,54	1,53	1,53	1,53
Chemical A	5,02	5,04	4,95	5,00
Chemical A (1/16)	1,43	1,42	1,44	1,43

All conductivity measurements of alcohol repellent chemicals and their averages are given in **Table.4.2**

Table.4.2. Conductivity measurements of Alcohol Repellent Chemicals

Conductivities of Chemicals	1 ($\mu\text{s/cm.}$)	2 ($\mu\text{s/cm.}$)	3 ($\mu\text{s/cm.}$)	Averages ($\mu\text{s/cm.}$)
Chemical C (1/2)	2564	2555	2553	2557,33
Chemical C(1/3)	1743	1743	1741	1742,33
Chemical C(1/4)	1237	1238	1240	1238,33
Chemical C(1/8)	967	940	938	948,33
Chemical C(1/16)	488	497	490	491,67
Chemical B (1/2)	637	641	640	639,33
Chemical B(1/3)	500	505	506	503,66
Chemical B(1/4)	412	419	416	415,67
Chemical B(1/8)	364	368	365	365,67
Chemical B(1/16)	199	205	224	209,33
Chemical A (1/2)	2068	2079	2074	2073,67
Chemical A(1/3)	1733	1717	1712	1720,67
Chemical A(1/4)	1310	1306	1302	1306
Chemical A(1/8)	1165	1162	1154	1160,33
Chemical A(1/16)	601	597	599	599

*The ratios in parenthesis indicate the dilution ratios of chemicals with distilled water.
(Finishing Agent/Distilled water)

Surface tension measurements of alcohol repellent chemicals and all measurements are given in **Table.4.3.**

Table.4.3. Surface Tension measurements of Alcohol Repellent Chemicals

Surface Tension of Chemicals	1 (mN/m.)	2 (mN/m.)	3 (mN/m.)	4 (mN/m.)	Averages (mN/m.)
Chemical C (1/2)	33,47	32,54	33,51	31,98	32,87
Chemical C(1/3)	33,13	32,8	32,95	33,88	33,19
Chemical C(1/4)	35,58	33,62	34,07	34,22	34,37
Chemical C (1/8)	32,58	32,03	32,46	32,45	32,38
Chemical C(1/16)	35,44	35,78	35,41	35,88	35,62
Chemical B (1/2)	33,82	34,02	33,85	32,79	33,62
Chemical B(1/3)	37,7	37,86	38,48	38,12	38,04
Chemical B (1/4)	39,03	39,81	39,98	40,34	39,79
Chemical B (1/8)	32,58	32,03	32,46	32,43	32,37
Chemical B (1/16)	30,77	30,65	30,43	31,04	30,72
Chemical A (1/2)	33,38	32,89	33,76	33,24	33,31
Chemical A (1/3)	35,09	34,72	34,41	34,2	34,60
Chemical A (1/4)	35,09	34,43	34,24	34,68	34,61
Chemical A (1/8)	36,07	36,12	36,57	36,24	36,25
Chemical A (1/16)	43,07	42,08	42,31	43,32	42,69

*The ratios in parenthesis indicates the dilution ratios of chemicals with distilled water (Finishing Agent/Distilled water).

The results showed that each chemical has different solution properties. One of the important properties in electrospray application is conductivity. The conductivity values of the electrospray solutions must be greater than 10^{-8} ns.cm⁻¹ [5]. The measurement results showed that the conductivity results of all chemical materials were well above the limit of electrospray. This is the reason why the primeval values of the materials will not have a negative effect on the electrospraying of chemical materials.

The chemical materials were also subjected to surface tension measurements at the respective concentrations. These values are given in Table 4.3. Some investigators have studied the effects of surface tension on the electrospray for

polyvinylpyrrolidone (PVP) and reported that the surface tension of the solutions should not be higher than 50 mN.m⁻¹ [6]. The surface tension values for all concentrations of the chemicals used in the study are found to be below 50mN.m⁻¹. Hence, the results of surface tension of all alcohol-repellent chemicals are suitable for electro spraying conditions. When the dilution ratios of the chemicals are considered, the most appropriate ratio is 1/16.

4.2. Comparison of consumption rate of alcohol repellent materials at processes

In the literature, there are different methods used in wet finishing operations of fabrics. In this study, it was aimed to analyze the use, advantages and disadvantages of the electro spray application method which is a new method for the application of finishing materials. However, kiss-roll and pad-dry methods have also been used to compare the method with other methods. Each finishing process has a different process. Chemical material manufacturers recommend a prescription that will give the result of optimization according to the method. Therefore, the amount of solution proposed by the manufacturer can vary. However, since the comparison of results is aimed in this study, the same amount of chemical material was used in each of the three methods.

All methods and amounts of alcohol-repellent chemical materials were calculated and tabulated. The amounts of three different chemical materials used in the Pad-dry method were calculated and the results are given in Table 4.4, Table 4.5 and Table 4.6. Similarly, the amounts of three different chemical materials in the kiss-roll method are given in Table 4.7, Table 4.8 and Table 4.9. The amounts of materials used for electro spray application are shown in Table 4.10, Table 4.11 and Table 4.12.

Table 4.4. Pad-dry method, Chemical A (40gr/lit)

Pad-dry method –Chemical A - 40gr/lit						
Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6539	3,9908	2,3369	2,2829	0,0913
	35 gr/m ²	1,6502	3,8792	2,229		
	45 gr/m ²	2,0101	5,2324	3,2223	3,2177	0,1287
	45 gr/m ²	2,0165	5,2297	3,2132		
Woven Fabrics	100% PES	15,6213	28,518	12,8967	13,1024	0,5240
	100% PES	15,8123	29,1204	13,3081		
	65/35% PES/CO	16,1293	32,084	15,9547	15,7014	0,6280
	65/35% PES/CO	16,2536	31,7017	15,4481		

Table 4.5. Pad-dry method, Chemical B (40gr/lit)

Pad-dry method - Chemical B - 40gr/lit						
Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6341	4,0682	2,4341	2,3402	0,0936
	35 gr/m ²	1,6452	3,8915	2,2463		
	45 gr/m ²	2,014	5,156	3,142	3,0637	0,1225
	45 gr/m ²	2,0015	4,987	2,9855		
Woven Fabrics	100% PES	15,9101	28,967	13,0569	13,1869	0,5274
	100% PES	15,7032	29,0201	13,3169		
	65/35% PES/CO	16,4723	31,8976	15,4253	15,3568	0,6142
	65/35% PES/CO	16,8214	32,1097	15,2883		

Table 4.6.Pad-dry method, Chemical C (40gr/lit)

Pad-dry method - Chemical C - 40gr/lit						
Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6115	3,8655	2,254	2,3169	0,0926
	35 gr/m ²	1,6854	4,0653	2,3799		
	45 gr/m ²	1,9945	5,145	3,1505	3,2078	0,1283
	45 gr/m ²	2,0025	5,2676	3,2651		
Woven Fabrics	100% PES	15,9973	29,2394	13,2421	13,3382	0,5335
	100% PES	16,026	29,4603	13,4343		
	65/35% PES/CO	16,5227	32,225	15,7023	15,5252	0,6210
	65/35% PES/CO	16,505	31,8532	15,3482		

Table 4.7.Kiss-roll method, Chemical A(60gr/lit.)

Kiss-roll - Chemical A - 60gr/lit						
Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6634	3,1976	1,5342	1,5375	0,0922
	35 gr/m ²	1,6484	3,1892	1,5408		
	45 gr/m ²	1,9876	3,9845	1,9969	2,0213	0,1212
	45 gr/m ²	2,0755	4,1212	2,0457		
Woven Fabrics	100% PES	15,5092	24,5643	9,0551	9,0947	0,5456
	100% PES	15,7865	24,9208	9,1343		
	65/35% PES/CO	16,3744	26,8221	10,4477	10,3029	0,6181
	65/35% PES/CO	15,9984	26,1566	10,1582		

Table 4.8.Kiss-roll method, Chemical B(60 gr/lit.)

Kiss-roll –Chemical B 60gr/lit						
Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6343	3,0124	1,3781	1,5902	0,0954
	35 gr/m ²	1,6843	3,4867	1,8024		
	45 gr/m ²	1,9244	3,9542	2,0298	2,1672	0,13
	45 gr/m ²	2,2056	4,5103	2,3047		
Woven Fabrics	100% PES	15,3432	24,332	8,9888	8,6834	0,521
	100% PES	15,7664	24,1445	8,3781		
	65/35% PES/CO	16,1907	26,7098	10,5191	10,4177	0,6250
	65/35% PES/CO	16,7643	27,0807	10,3164		

Table 4.9.Kiss-roll method, Chemical C (60 gr/lit.)

Kiss-roll Chemical C 60gr/lit						
Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6544	3,1401	1,4857	1,5577	0,0934
	35 gr/m ²	1,6634	3,2932	1,6298		
	45 gr/m ²	1,9502	4,0999	2,1497	2,0446	0,1226
	45 gr/m ²	2,0056	3,9451	1,9395		
Woven Fabrics	100% PES	15,3923	24,332	8,9397	8,6628	0,5197
	100% PES	15,4556	23,8415	8,3859		
	65/35% PES/CO	15,902	25,344	9,442	10,4665	0,6279
	65/35% PES/CO	16,2112	27,7022	11,491		

Table 4.10.Electrospray parameters.

Alcohol Repellent Materials (1/16)	Fabric Types	Applied Solution (ml)	Voltage (kV)	Distance (cm)	Degree (C ⁰)
Chemical A (1/16)*	35 gr/m ²	1,472	(+)35, (-) 15	7	25
	45gr/m ²	2,048	(+)35, (-) 15	7	25
	%100 PES	8,384	(+)35, (-) 15	7	25
	%65 Co %35 PES	10,048	(+)35, (-) 15	7	25
Chemical B (1/16)*	35 gr/m ²	1,472	(+)30, (-)10	7	25
	45gr/m ²	2,048	(+)30, (-)10	7	25
	%100 PES	8,384	(+)30, (-)10	7	25
	%65 Co %35 PES	10,048	(+)30, (-)10	7	25
Chemical C (1/16)*	35 gr/m ²	1,472	(+)30, (-)10	7	25
	45gr/m ²	2,048	(+)30, (-)10	7	25
	%100 PES	8,384	(+)30, (-)10	7	25
	%65 Co %35 PES	10,048	(+)30, (-)10	7	25

* The ratios in parenthesis indicates the dilution ratios of chemicals with distilled water. (Finishing Agent/Distilled water)

Table 4.11.Electrospraying method, Chemical A

Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6544	2,9903	1,3359	1,3376	0,0836
	35 gr/m ²	1,6632	3,0025	1,3393		
	45 gr/m ²	1,9502	3,8089	1,8587	1,8361	0,1147
	45 gr/m ²	2,0056	3,8191	1,8135		
Woven Fabrics	100% PES	15,3923	22,9645	7,5722	7,5594	0,4724
	100% PES	15,4556	23,0023	7,5467		
	65/35% PES/CO	15,902	25,1404	9,2384	9,1637	0,5727
	65/35% PES/CO	16,2112	25,3002	9,089		

Table 4.12.Electrospraying method, Chemical B

Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6424	2,9775	1,3351	1,3421	0,0838
	35 gr/m ²	1,6512	3,0003	1,3491		
	45 gr/m ²	1,9432	3,7886	1,8454	1,8397	0,1149
	45 gr/m ²	1,9855	3,8195	1,834		
Woven Fabrics	100% PES	15,992	23,6645	7,6725	7,5551	0,4721
	100% PES	15,765	23,2028	7,4378		
	65/35% PES/CO	15,9162	25,1387	9,2225	9,1615	0,5725
	65/35% PES/CO	16,1123	25,2128	9,1005		

Table 4.13.Electrospraying method with Chemical C

Fabric Types	Fabric class	Dry Weights (gr.)	Wet weights (gr.)	Chemical Solution on Fabric (gr.)	Averages of Chemical Solution on Fabrics (gr.)	Chemical Consumption at This Process (gr.)
Nonwoven Fabrics	35 gr/m ²	1,6742	3,0311	1,3569	1,3482	0,0842
	35 gr/m ²	1,673	3,0125	1,3395		
	45 gr/m ²	1,9706	3,8084	1,8378	1,8456	0,1153
	45 gr/m ²	2,0356	3,8891	1,8535		
Woven Fabrics	100% PES	15,3235	22,9641	7,6406	7,5432	0,4714
	100% PES	15,5562	23,002	7,4458		
	65/35% PES/CO	16,102	25,2904	9,1884	9,1437	0,5714
	65/35% PES/CO	16,2112	25,3102	9,099		

First, the tests were started with the classic method pad-dry. The rates of chemical materials used in the pad-dry method are determined to depend on the rates given by

the manufacturers. Accordingly, all the chemicals (A, B and C) were prepared to be 40 gr/liter in the pad-dry method and applied to the fabrics as described in Table.3.5. In the kiss-roll application, the same amount of chemical finishing material is transferred to the fabric, although the manufacturer's recommendation is different so that the performance differences of the methods used be analyzed well. However, in the case of kiss-roll application, the solution concentration is taken as 60 gr/liter.

Table 4.4, 4.5, 4.6, 4.7, 4.8 and 4.9 indicate resultant data with pad-dry and kiss-roll methods. The amount of solution that the fabric weighed before the application in the tables, after application, was calculated in grams (grams). The "Chemical Solution on Fabric" column was calculated by taking the wet fabric weight to dry fabric weight. The weights of the fabrics before and after the application were given in the tables. The difference between these two measurements corresponds to the amount of solution transferred to the fabric (in grams). This difference is given in the "Chemical Solution on Fabric" column. The measurements on each fabric were repeated twice to get more accurate results and the average of the two measurements taken "Averages of chemical solution on fabrics". The "Chemical consumption at this process" column indicates the amount of pure chemical consumption on the fabric, based on the amount of solution determined in the previous column.

The chemical consumption of fabrics was calculated in the last column by the ratio to the average chemical solutions by regarding the concentrations of finishing materials. These tables show that as a result of the application, the amount of chemical materials transferred onto the fabric is very close to each other. In order to equalize the amounts of finishing materials transferred to the fabrics, the pressure between the cylinders was a parameter in the pad-dry method, similarly the lower cylinder speed and pressure between cylinders were used as parameters in the kiss-roll application. In the electrospray method the application period was used to control the amount of material which was transferred onto the fabrics.

The parameters and chemical solution amounts used for electrospray application are given in Table 4.10. In this method, application time and concentration variables are used to control the amount of chemicals to be transferred to the fabrics. The solution to be used in the electrospray method was diluted 1/16 to ensure homogenous

distribution on the fabric surface. In Table 4.11, 4.12 and 4.13 the data obtained on nonwoven and woven fabrics after application by electrospray method are given.

4.3. Test Results

In this study, woven fabrics (65/35% PES / Co and 100% PES) and nonwoven fabrics were selected at different weights of 35gr / m² and 45 gr / m² and the alcohol repellent chemicals were determined as Chemical A, B and C. Finishing operations were applied to the fabrics using the pad-dry, kiss-roll and electrospray methods detailed above. The fabrics were then evaluated according to the alcohol repellent values according to the "AATCC 193-2005 Aqueous Liquid repellency Water / alcohol Solution Resistance" test method (see Table 4.14)

Tablo 4.14. AATCC 193-2005 rating factors

AATCC Aqueous Solution Repellency Grade Number	Composition
0	None (fails 98% water)
1	98:2/Water : isopropyl alcohol (vol:vol)
2	95:5/Water : isopropyl alcohol (vol:vol)
3	90:10/Water : isopropyl alcohol (vol:vol)
4	80:20/Water : isopropyl alcohol (vol:vol)
5	70:30/Water : isopropyl alcohol (vol:vol)
6	60:40/Water : isopropyl alcohol (vol:vol)
7	50:50/Water : isopropyl alcohol (vol:vol)
8	40:60/Water : isopropyl alcohol (vol:vol)

According to this evaluation system, the fabrics were rated according to the alcohol repulsion ratios. The woven fabrics which are desired to have a washing resistance are subjected to washing cycles of 1, 5, 10, 15 and 25 according to ISO 105 C06-A2S standard and then tested after drying in ambient conditions. Accordingly, the results of the electrospray method are given in Table 4.15, the results of the pad-dry method are given in Table 4.16 and the kiss-roll results are given in Table 4.17 for the woven fabrics. The evaluation results of non-woven fabrics according to the specified standard are given in Table 4.18 for the electrospray method, Table 4.19 for the pad-

dry method and Table 4.20 for the kiss-roll method. All results also shown with graphics at Table 4.21, 4.22 and 4.23.

Table 4.15.Alcohol repellent test results for the woven fabrics at different washing cycles(electrospray method).

Electrosprayed Alcohol Repellent Materials to Woven Fabrics Which Applied Laundering Cycles Results							
Laundering Cycle Times	Test Method	Chemical A		Chemical B		Chemical C	
		%100 PES - Plain	%65/35 PES/Co - Woven	%100 PES - Plain	%65/35 PES/Co - Woven	%100 PES - Plain	%65/35 PES/Co - Woven
0	AATCC 193-2005	8	8	8	8	8	8
1	AATCC 193-2005	8	8	8	6	8	8
5	AATCC 193-2005	8	8	8	5	8	8
10	AATCC 193-2005	8	7	7	5	8	7
15	AATCC 193-2005	8	6	7	5	8	7
25	AATCC 193-2005	4	3	3	3	3	2

Table 4.16.Alcohol repellent test results for the woven fabrics at different washing cycles (pad-dry method).

Pad-Dry Method - Alcohol Repellent Materials to Woven Fabrics Which Applied Laundering Cycles Results							
Laundering Cycle Times	Test Method	Chemical A		Chemical B		Chemical C	
		%100 PES - Plain	%65/35 PES/Co - Woven	%100 PES - Plain	%65/35 PES/Co - Woven	%100 PES - Plain	%65/35 PES/Co - Woven
0	AATCC 193-2005	8	8	8	8	8	8
1	AATCC 193-2005	8	8	8	5	8	8
5	AATCC 193-2005	8	8	8	5	8	7
10	AATCC 193-2005	8	7	8	5	8	7
15	AATCC 193-2005	8	5	8	5	8	5
25	AATCC 193-2005	4	1	3	0	4	1

Table 4.17.Alcohol repellent test results for the woven fabrics at different washing cycles (kiss-roll method).

Kiss-roll Method- Alcohol Repellent Materials to Woven Fabrics Which Applied Laundering Cycles Results							
Laundering Cycle Times	Test Method	Chemical A		Chemical B		Chemical C	
		%100 PES - Plain	%65/35 PES/Co - Woven	%100 PES - Plain	%65/35 PES/Co - Woven	%100 PES - Plain	%65/35 PES/Co - Woven
0	AATCC 193-2005	8	8	8	8	8	8
1	AATCC 193-2005	7	5	8	7	7	7
5	AATCC 193-2005	5	5	8	7	6	6
10	AATCC 193-2005	5	5	8	7	6	5
15	AATCC 193-2005	4	4	8	7	6	5
25	AATCC 193-2005	1	0	4	3	3	1

Table 4.18.Alcohol repellent test results for the nonwoven fabrics (Electrospray method).

	Chemical A		Chemical B		Chemical C	
Test Method	35 gr/m ²	45 gr/m ²	35 gr/m ²	45 gr/m ²	35 gr/m ²	45 gr/m ²
AATCC 193-2005	7	8	7	8	8	8

Table 4.19.Alcohol repellent test results for the nonwoven fabrics (Pad-dry method).

	Chemical A		Chemical B		Chemical C	
Test Method	35 gr/m ²	45 gr/m ²	35 gr/m ²	45 gr/m ²	35 gr/m ²	45 gr/m ²
AATCC 193-2005	7	8	7	8	8	8

Table 4.20.Alcohol repellent test results for the nonwoven fabrics (Kiss-roll method).

	Chemical A		Chemical B		Chemical C	
Test Method	35 gr/m ²	45 gr/m ²	35 gr/m ²	45 gr/m ²	35 gr/m ²	45 gr/m ²
AATCC 193-2005	7	8	8	8	7	8

Table 4.21. Electrospray test results

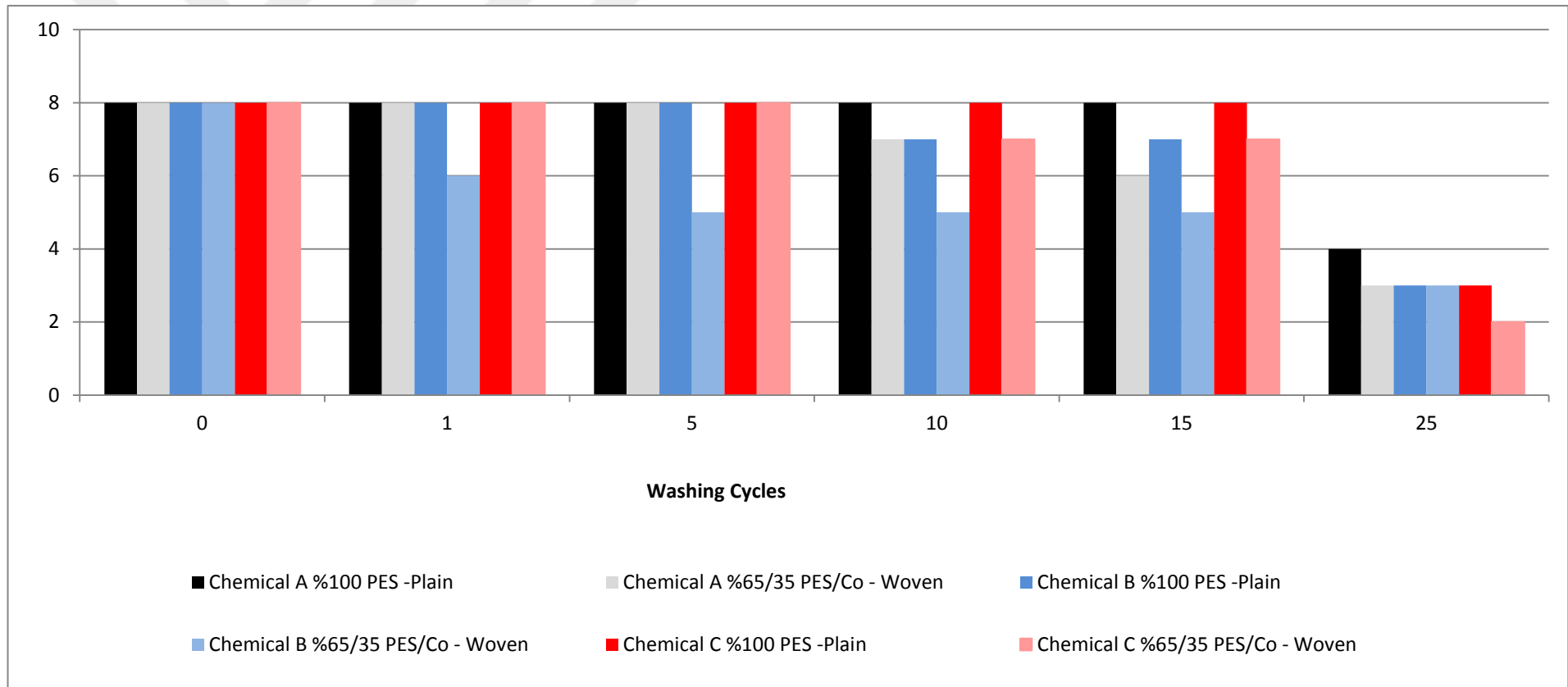


Table 4.22. Pad-dry test results

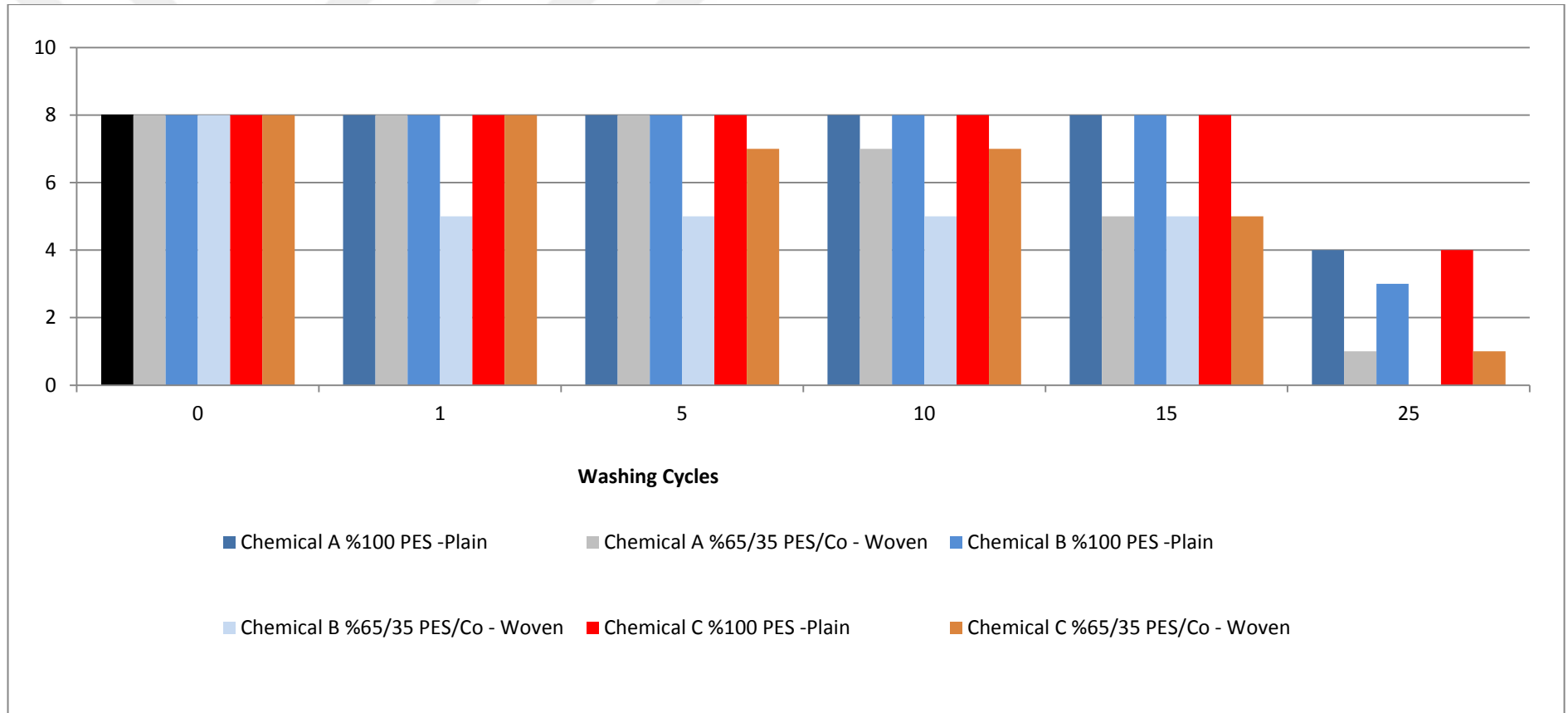
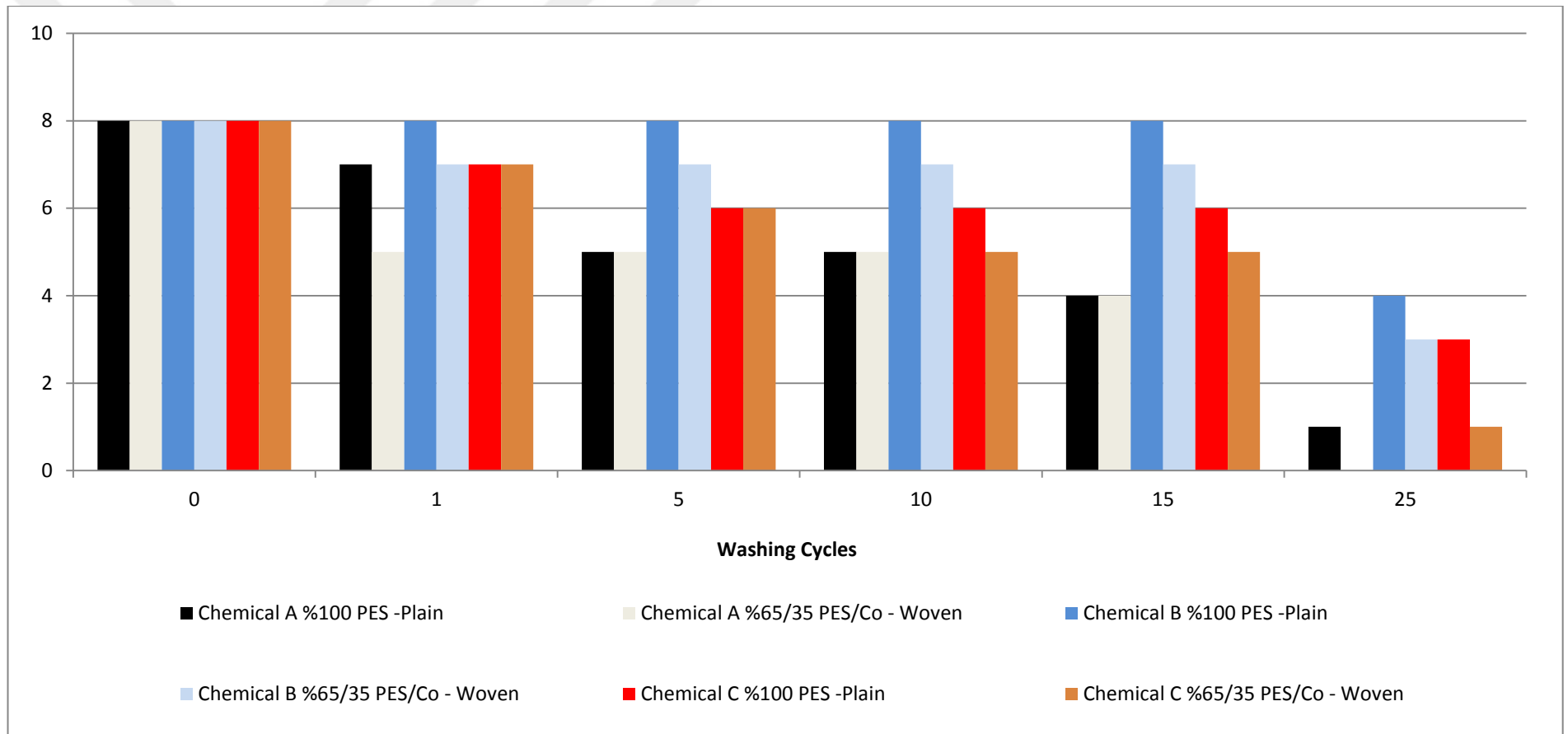


Table 4.23 Kiss-roll test results



4.3.1. Statistical Analysis

In order to analyze the performance of the methods used, one-way ANOVA was performed with the SPSS 22 statistical data analysis package program for the data obtained after washing cycles for the woven fabrics in the above tables. One-way analysis of variance (ANOVA) is used to calculate the difference between three independent mean values for a normalized population. Since the chemical quantities in the methods were applied to equal fabric, chemical differences were not considered. According to this; Each washing cycle was evaluated according to two different types of fabric in itself, and the results are given below.

4.3.1.1. %100 PES Fabric

Table 4.21. 1 Wash Cycle alcohol repellency average value for 100% PES fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	8	0	4	0,079
	Pad-dry	3	8	0		
	Kiss-roll	3	7,333	0,577		

One-way analysis of variance (ANOVA) was used to determine whether the average values of the alcohol repellency values of the PES fabrics differed significantly according to the methods for 1 wash cycle. The results of the analysis show that the difference between the group averages is not statistically significant ($p > 0.05$). The results of the analysis show that the performances of the methods are close to each other. In other words, it shows that one of the methods is not superior to the other.

Tablo 4.22. 5 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	8	0	3,571	0,095
	Pad-dry	3	8	0		
	Kiss-roll	3	6,333	1,528		

One-way analysis of variance (ANOVA) was used to determine whether the average values of the alcohol repellency values of the PES fabrics differed significantly

according to the methods for 5 wash cycles. The results of the analysis show that the difference between the group averages is not statistically significant ($p > 0.05$).

Tablo 4.23 10 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	7,667	0,577	2,625	0,152
	Pad-dry	3	8	0		
	Kiss-roll	3	6,333	1,528		

One-way analysis of variance (ANOVA) was used to determine whether the average values of the alcohol repellency values of the PES fabrics differed significantly according to the methods for 10 wash cycles. The results of the analysis show that the difference between the group averages is not statistically significant ($p > 0.05$).

Tablo 4.24. 15 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	7,667	0,577	0,864	0,468
	Pad-dry	3	7	1,732		
	Kiss-roll	3	6	2		

One-way analysis of variance (ANOVA) was used to determine whether the average values of the alcohol repellency values of the PES fabrics differed significantly according to the methods for 15 wash cycles. The results of the analysis show that the difference between the group averages is not statistically significant ($p > 0.05$).

Tablo 4.25. 25 Wash Cycles alcohol repellency average value for 100% PES fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	3,333	0,577	0,267	0,775
	Pad-dry	3	2,667	1,528		
	Kiss-roll	3	2,667	1,528		

One-way analysis of variance (ANOVA) was used to determine whether the average values of the alcohol repellency values of the PES fabrics differed significantly according to the methods for 25 wash cycles. The results of the analysis show that the difference between the group averages is not statistically significant ($p > 0.05$).

4.3.1.2. 65/35 Pes/Co Fabric

Tablo 4.26. 1 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	7,333	1,155	0,412	0,68
	Pad-dry	3	7	1,732		
	Kiss-roll	3	6,333	1,155		

As a result of one way analysis of variance (ANOVA) the average alcohol repellency values of the 65/35 PES/CO fabrics did not show a significant difference according to the methods for 1 Wash Cycles ($p > 0.05$). The results of the analysis show that the performances of the methods are close to each other.

Tablo 4.27. 5 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	7	1,732	0,368	0,706
	Pad-dry	3	6,667	1,528		
	Kiss-roll	3	6	1		

As a result of one way analysis of variance (ANOVA) the average alcohol repellency values of the 65/35 PES/CO fabrics did not show a significant difference according to the methods for 5 Wash Cycles ($p > 0.05$). The results of the analysis show that the performances of the methods are close to each other.

Tablo 4.28. 10 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	6,333	1,155	0,333	0,729
	Pad-dry	3	6,333	1,155		
	Kiss-roll	3	5,667	1,155		

As a result of one way analysis of variance (ANOVA) the average alcohol repellency values of the 65/35 PES/CO fabrics did not show a significant difference according to the methods for 10 Wash Cycles ($p > 0.05$). The results of the analysis show that the performances of the methods are close to each other.

Tablo 4.29. 15 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	6	1	0,7	0,533
	Pad-dry	3	5	0		
	Kiss-roll	3	5,333	1,528		

As a result of one way analysis of variance (ANOVA) the average alcohol repellency values of the 65/35 PES/CO fabrics did not show a significant difference according to the methods for 15 Wash Cycles ($p > 0.05$). The results of the analysis show that the performances of the methods are close to each other.

Tablo 4.30. 25 Wash Cycles alcohol repellency average value for 65/35 PES/CO fabric according to methods.

	Grup	N	Ort	Ss	F	p
Alcohol repellency	Elektrospray	3	2,667	0,577	3,8	0,086
	Pad-dry	3	1	0		
	Kiss-roll	3	1,667	1,155		

As a result of one way analysis of variance (ANOVA) the average alcohol repellency values of the 65/35 PES/CO fabrics did not show a significant difference according to the methods for 25 Wash Cycles ($p > 0.05$). The results of the analysis show that the performances of the methods are close to each other.

CHAPTER 5

CONCLUSIONS

5.1 Conclusions

In this study, it is aimed to compare and analyze the performances of newly introduced electrospray method and conventional pad-dry and kiss-roll methods for textile finishing operations. For this purpose, alcohol finishing material were applied to nonwoven and woven fabrics by electrospray, pad-dry and kiss-roll methods and the results were analyzed according to performances obtained from the practical study. Electrospray method is a new and successful technique which is easy to apply in the modification of textile surfaces. This method has many advantages over conventional application methods (pad-dry and kiss-roll). The drying processes required to evaporate the water in the solutions in the finishing applications are a significant cost to the processes. However, electrospray method requires less energy consumption than pad-dry method. The amount of solution applied is shown in Table.4.4, 4.4.5.5 and 4.4.6 in the pad-dry method and the amount of solution used in the electrospray method is shown in 4.12 4.13 and 4.14 proving that the same effects can be obtained by using less water. In the pad-dry method, the entire fabric is dipped into the solution. In this method, it is possible to reduce the consumption of costly finishing material by applying to one surface of fabric and to prevent the skin contact with the finished fabric surface to protect against harmful chemical substances.

It has been observed that some disadvantages in the kiss-roll method used to apply single-surface finishing in the sector are eliminated by this method. The biggest disadvantage of the kiss-roll method is that non-homogenous distribution of the finishing material on the surface of fabrics because of the pressure differences along the length of the cylinders. On the other side electrospraying performs homogeneous

distribution and the desired effect can be obtained evenly on the whole surface. In this study, it was aimed to determine the performance differences of the pad-dry and kiss-roll methods used in the finishing operations according to the electro spray method. However, the results given in Tables 4.10, 4.11, 4.12, 4.13, 4.14 and 4.15 show that the alcohol repellent performance results of the electro spray method are good as much as the performance obtained from pad-dry and kiss-roll methods. All the results were obtained according to AATCC's standard test method.

In this study, the solutions were prepared using 3 different commercial chemicals, and the chemical amounts applied to the fabrics were equalized because the methods were compared to examine the performance difference. The results show that, in both woven and non-woven fabrics, alcohol repellent capability of all methods are very close to each others. In data of one-way ANOVA applied in SPSS 22 program; chemical differences were not considered since chemical quantities in the methods were applied at equal amount to the fabric. Each washing cycle was evaluated according to two different fabric types, and no significant difference was found in the results. According to the result, the electro spray method was supported by statistical data and found to be at least as successful as other methods.

Therefore, it has been concluded that electro spray method is an effective and successful method in producing alcohol repellent fabric due to the advantages mentioned above. Electro spray parameters have been optimized for small scale installations and successful applications have been demonstrated. Electro spray method is not widely used in industry. In future studies, it may be possible to provide new data to be obtained by making different chemical selections of the electro spray method (water, oil, dirt repellent, silicon etc.) and changing quantities.

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