JANUARY, 2014 **M. Sc. THESIS in TEXTILE ENGINEERING** **MUSTAFA SAİD ÇAKALLI**

UNIVERSITY OF GAZİANTEP

GRADUATE SCHOOL OF NATURAL&APPLIED SCIENCES

INVESTIGATION OF SOME PERFORMANCE PROPERTIES OF SPUNLACE NONWOVEN FABRICS PRODUCED BY POLYESTER AND VISCOSE FIBERS

M. Sc. THESIS

IN

TEXTILE ENGINEERING

BY

MUSTAFA SAİD ÇAKALLI

JANUARY 2014

Investigation of Some Performance Properties of Spunlace Nonwoven Fabrics Produced by Polyester and Viscose Fibers

M. Sc. Thesis

in

Textile Engineering

University of Gaziantep

Supervisor: Prof. Dr. Mehmet TOPALBEKİROĞLU

by

Mustafa Said ÇAKALLI

January 2014

T. C.
UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES
TEXTILE ENGINEERING DEPARTMENT

Name of the thesis: Investigation of Some Performance Properties of Spunlace Nonwoven Fabrics Produced by Polyester and Viscose Fibers

Name of the student: Mustafa Said ÇAKALLI

Exam date: 27.01.2014

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.

Prof. Dr. Mehmet TOPALBEKİROĞLU
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 for the degree of Master of Science.

Prof. Dr. Mehmet TOPALBEKİROĞLU
Supervisor

Examining Committee Members	Signature
1. Prof. Dr. Mehmet TOPALBEKİROĞLU	....
2. Prof. Dr. Hüseyin BOZKURT	....
3. Assoc. Prof. Dr. Cem GÜNEŞOĞLU	....
4. Asst. Prof. Dr. Nazan AVCIOĞLU KALEBEK	....
5. Asst. Prof. Dr. Mehmet Erdem İNCE	....

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

Mustafa Said ÇAKALLI

ABSTRACT

INVESTIGATION OF SOME PERFORMANCE PROPERTIES OF SPUNLACE NONWOVEN FABRICS PRODUCED BY POLYESTER AND VISCOSE FIBERS

ÇAKALLI, Mustafa Said

M.Sc. in Textile Engineering

Supervisor: Prof. Dr. Mehmet TOPALBEKİROĞLU

January 2014. 109 Pages

Nowadays nonwoven industry has become fairly important in the textile industry due to large application field in many areas. Nonwoven industry has reached the top level day by day in current production amount thanks to increasing its investment, and it keeps continuing its growths in high speed, due to more economical production and productivity in less time all over the world. Nonwovens are produced by different production techniques depending on usage areas. Spunlace nonwoven is referred to one of this production technique of nonwoven, which is obtained by the method of fibers to be interlaced with water jet to each other. Spunlace fabrics are used many areas in our daily lives such as hygienic wipes, diaper fabrics, medical fabrics, and hair towels.

In this thesis spunlace fabrics which were produced by polyester and viscose fibers in different blend ratios and weights were investigated performance properties such as thickness, whiteness, absorbency time and capacity, tear resistance, tensile strength and elongation at break. Effect of fabric weight and blend fiber on these performance properties were examined. Obtained results were investigated in statistical terms and ANOVA analysis was determined. In addition, correlation analysis was performed to examine the relationship between fabric weight, blend ratio of polyester - viscose fiber and performances properties. According to obtained test results it was determined that fabric weight and blended polyester-viscose fibers were found significant effects on the performance properties.

Key words: Nonwoven, spunlace performance properties, statistical analysis, viscose, polyester.

ÖZET

POLYESTER VE VİSKON LİFLERİNDEN ÜRETİLEN SPUNLACE DOKUSUZ KUMAŞLARIN BAZI PERFORMANS ÖZELLİKLERİNİN İNCELENMESİ

ÇAKALLI, Mustafa Said

Yüksek Lisans Tezi, Tekstil Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Mehmet TOPALBEKİROĞLU

Ocak 2014. 109 Sayfa

Günümüzde dokusuz kumaşlar, birçok kullanım alanına sahip olmasından dolayı tekstil endüstrisinde çok önemli bir yere sahiptir. Her geçen yıl artan yatırımlar sayesinde üretimde üst noktalara ulaşan dokusuz kumaş sektörü, tüm dünyada daha ekonomik, daha az zamanda üretimi ve verimliliği nedeniyle hızla büyümeye devam etmektedir. Dokusuz kumaşlar kullanım amacına göre farklı teknikler ile üretilmektedirler. Bu üretim tekniklerinden birisi olan spunlace; su jeti ile liflerin birbirine dolaştırılması sonucu oluşan dokusuz kumaşlara denilmektedir. Spunlace kumaşlar ıslak mendiller, çocuk bezleri, medikal kumaşlar, saç havluları gibi birçok alanda kullanılmaktadır.

Bu tezde polyester ve viskoz liflerinden farklı karışım oranlarında ve ağırlıklarında üretilmiş spunlace dokusuz kumaşların kalınlık, kopma mukavemeti ve uzaması, yırtılma direnci, emme kapasitesi ve süresi, beyazlık performans özellikleri ilgili testler yapılarak incelenmiştir. Kumaş ağırlığı ve karışım oranının bu performans özellikleri üzerine etkileri incelenmiştir. Elde edilen sonuçlar istatistiksel açıdan değerlendirilmiş ve ANOVA analizi yapılmıştır. Ayrıca korelasyon ve regresyon analizi yapılarak, kumaş ağırlığı, polyester-viskoz karışımları ve performans özellikleri arasındaki ilişkiler incelenmiştir. Yapılan istatistiksel analiz sonuçlarına göre polyester-viskoz karışım oranının ve kumaş ağırlığının belirlenen performans özelliklerine önemli derecede etkisi olduğu belirlenmiştir.

Anahtar kelimeler: Dokusuz yüzey, Spunlace performans özellikleri, istatistiksel analiz, viskoz, polyester.

ACKNOWLEDGMENTS

My endless thanks and gratitude to the kindness and generosity of my supervisor and advisor **Prof. Dr. Mehmet TOPALBEKİROĞLU** who supports me anytime, whenever I interrupt to him, he never let me down, even contrarily he gives precious time for me and behaves to me rather than coach, like friend, during my master degree term especially in this studying.

I would like to express my deepest appreciation and special thanks to **Research Assistants Dr. Halil İbrahim ÇELİK** for supporting me in every part of my study.

I am greatly thanks to my Committee Members **Prof. Dr. Hüseyin BOZKURT, Assoc. Prof. Dr. Cem GÜNEŞOĞLU**, **Asst. Prof. Dr. Nazan KALEBEK, and Asst. Prof. Dr. Mehmet Erdem İNCE.**

I would like to the deepest gratitude to **MOGUL TEXTILE COMPANY, primarily Regulatory Affairs & Business Development Manager Orkun BAYRAM**, **Sales Representative Çağdaş YAZ**, **Quality Control Manager Deniz DEVECİLER, Textile Engineer Recep KABACAN** and **Biologist Suat TAZEOGLU**, also **Instructor Cemile Emel KIRLANGIÇ** in **University of Gaziantep.**

I also grateful to Gaziantep University Academic Personnel, **Research Assistants Dr. H.Kübra KAYNAK, Dr. Züleyha DEĞİRMENCİ, Halil İbrahim İÇOĞLU** and **Esin SARIOĞLU**

I am greatly thanks to my beloved family who still gave an accommodation to a man who was 30 years old, since the first day that I took breath I have been grateful to the almighty Allah so as to give me such a gorgeous family, my beloved father **İbrahim ÇAKALLI** and my mother **Fatma ÇAKALLI,** also to my sisters **Saide Nur KARAMAN** and **Sümeyye ÇAKALLI TÜYSÜZ** who are my wisdom people in order to give solution about my all matters and issues. In addition, to my friends who hang me out on my social life and business life **Tuğba SÖNMEZ, Mustafa TANRIVERDİ, Cumali DELİOĞLU, Yusuf TANRIVERDİ, Emrah BİRELLİ, Mehmet ÇELİK, YAŞAR TORUN GENÇLİK MERKEZİ CREW.**

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Acap	Absorbency Capacity
Atime	Absorbency Time
CD	Cross direction (weft direction)
CV (%)	Coefficient Variation
CV	Viscose
ECD	Elongation at Break CD
EMD	Elongation at Break MD
MD	Machine direction (warp direction)
PES	Polyester
TCD	Tensile Strength CD
TH	Thickness
TMD	Tensile Strength MD
TRMD	Tear Resistance MD
TRC	Tear Resistance CD
V0	100%Polyester
V30	30% Viscose and 70 %Polyester
V50	50% Viscose and 50% Polyester
V70	70% Viscose and 30%Polyester
V100	100% Viscose
WH	Whiteness
WSP	World Strategic Plan
W30	30 g/m^2
W50	50 g/ m^2
W80	80 g/ m^2

CHAPTER 1

INTRODUCTION

1.1. Introduction

Nonwoven sector is defined as an area which is different from traditional textile industry; and it is one of the most important sections of the production. Thanks to leading textile manufacturers show a special interest in this area, commercial activities tend to increase the production of nonwovens. Known as non-woven fabric are used in many areas today. Nonwovens can be summarized in the form of non-woven and knitted textiles operation which performed with the advanced technology, natural or synthetic fibers combining with flat web formation. Nonwoven products are used in many specialized areas, ranging from liquid-absorbent or liquid repellent, flexible, soft or stiff, flame retardant, to antibacterial filtration and single-use with features such as long life or health care field, automotive, home textiles clothing. It also has a history of over 40 years in the industrial production of nonwoven that are more economical and faster production rate than classical weaving and knitting, it has also significant about production efficiency and reduction of costing [1].

In recent years, many new nonwoven-making technologies have been developed. Advances in man-made fibers, plastics and additives have been combined with process research and machinery development to open the way to new and important products. These developments have led to new fabric structures with valuable and marketable properties. New fibers, finishes and binders have been developed specifically for nonwovens. Also, has emerged efficient equipment designed to manufacture advanced nonwovens at high speeds. Equally impressive is the high speed equipment that dye, print, emboss, crimp and convert rolls goods into end-use products [1]. The nonwoven fabric properties depends on following particulars to an great extent.

- The choice of fibers,

- Technology which determines how the fibers are to be arranged,
- The bonding process and the bonding agent.

Fabric properties of nonwovens range from crisp to that soft to the touch to harsh, impossible to tear to extremely weak. This leads to a wide range of end products such as nappies, filters, teabags, geo textiles, etc. Some of which are durable and others are disposable [2].

Spunlace, Hydroentanglement, water jet needling, and hydraulic needling are synonymous terms used to describe a versatile process for bonding nonwoven fabrics [3]. In the spunlace process, a web of loose fibers is subjected to multiple rows of fine jets of highly pressurized water on a porous forming surface (endless belt or perforated drum) to form a nonwoven fabric [4]. During spunlace, fibers from the surface are inserted into the fibrous web by high velocity water jets. Hydraulic drag forces will bend and twist fibers and fiber bundles around themselves and other fibers, forming a series of small, interlocking knots [5]. Spunlace is considered as an energy transfer process by many researchers. It strengthens the array of loose fibers and imparts desired physical, tactile and aesthetics properties [6]. Hydroentangled fabrics rely primarily on fiber-to-fiber friction to achieve physical integrity and are characterized by relatively high strength, softness, drape and conformability [7].

1.2 Purpose

The aim of this study was to investigate some performance properties of spunlace nonwoven fabrics which were produced from polyester and viscose fiber. For this purpose effect of five different blend fiber (100% polyester, 70% polyester and 30% viscose, 50% polyester and 50% viscose, 30% viscose and 70% polyester 100% viscose) and effect of three different weight 30-50-80 g/m^2 on spunlace performance properties were examined. In this study, the effect of the fabric weight and fiber blend to some performance properties of spunlace nonwoven fabrics produced polyester and viscose fibers is investigated. As a result, this study will supply basic information and recommendation to nonwoven manufacturers which plan to produce the nonwoven fabrics. In addition, a literature review on nonwoven fabric performances will ensure a reference for researchers.

Spunlace performance properties were investigated as below;

- Thickness
- Tensile Strength and Elongation at Break
- Tear Resistance
- Absorbency Capacity
- Absorbency Time
- Whiteness

In this thesis, type of fibers were selected as the most commonly used fibers both polyester and viscose fibers. The reason was why polyester and viscose fiber blends in textile industry can be explained that polyester fibers offer excellent textile properties. Also high tenacity (dry and wet) results in good mechanical properties and durability. Furthermore, polyester shows good dimensional stability at a reasonable price. Problems can be indicated in wear comfort, as polyester is a hydrophobic fiber and thus cannot control humidity. Viscose fiber, on the contrary, illustrates water retention of 40% to 80%, and can thus easily control humidity. The fiber feels dry and comfortable on the skin. In combination with the soft handle viscose fibers offer excellent wear ability. The profiles of these two fibers suggest that combination of both fibers should result in an optimum for textile applications [8].

In context of the this thesis`s main part and content was summarized briefly as below. Properties and production methods described in "**Nonwoven Fabrics and Production Methods**" section, "**Materials and Methods**" section of the experimental part of the thesis sample nonwoven used as raw material properties of surfaces, was summarized production processes, the machines in manufacturing specifications.

In addition, to determine the performance properties of the standard test methods applied to fabrics and devices were reviewed briefly. Test methods described in experimental study carried out in the form of charts **“Experimental Results and Discussion”**

The results of analysis **“Conclusions and Recommendations”** issued collectively referred as the last section, within the scope of these made suggestions for the work that would be done in the future.

1.3. Previous Studying

In the literature, there were usually associated with non-woven production methods and the implementation of a new developed test methods and examined issues such as examining the effects of process parameters on the fabric performance. Spunlace non-woven fabric with based on the results the thesis according to the technique associated with the production of textiles which was reached and was thought to be directly related to topics sorted, the literature studies are ordered as follows;

Kalebek [9] designed and produced a prototype device with horizontal working principle. Weight, fiber type, and non-woven fabric samples were grouped by finishing processes on the experimental studies conducted in different friction surfaces. Samples were produced with 100% polypropylene (PP) (spun-bond technique) and 100% polyester (PES) (water-jet technologies). Tensile strength and elongation, thickness tests were applied so as to determine some of the physical characteristics of nonwoven fabrics used for sampling purposes. In addition, surface views before friction tests of the samples used were taken by digital stereo microscope and the computer connected to the microscope and examined. Spunlace non-woven fabric samples were obtained by the values of the coefficient of friction values were higher than spun bond samples. Spun-laced produced by method of the surface compared to fabrics produced using the spun bonded nonwoven fabric and the volume of the softer friction caused being constructed to be raising coefficients. In addition, in samples obtained by the method of spunlace fabric weight increases due to the structure that is made bulky and soft surface friction coefficient values increased well, whereas spun bond fabric weight measured by the increase in samples obtained from the tight and hard surface friction value [9].

Cincik [10] studied developing statistical models in order to predict the physical and performance properties of polyester/viscose blend needle punched nonwovens before fabric production. Different weight and blend fiber was produced three different densities the needle number of 75/cm^2, 150/cm^2, and 225/cm^2. In order to ensure; lay for each tissue was passed 1, 2 and 3 times as long as all other parameters stable the till last needling loom. Produced by five different blending, with four different weights and 3 different needling densities of 60 units of the fabric totally was used. It came to weight non-woven fabrics, thickness, density index, air permeability, bursting strength, abrasion resistance, absorbency capacity, dry / wet tensile strength and elongation at break, as well as physical and performance characteristics were determined using standard test methods and devices. Working as a result of all fabrics of polyester fiber with an increased thickness of the blend increased density was decreased both polyester fiber and viscose fiber groups. The weight of 125g/m^2 polyester fiber fabrics with the exception of an increase in the ratio of the blend fabrics for air permeability was increased, but it was reduced weight of 125 g/m^2. Due to the increasing of the polyester fibers in the structure, the capacity of water absorbency was increased. The fabric structure of the grip into the spaces larger amounts of liquid and absorbency capacity was increased [10].

Hajinai and Asgarian [11] investigated to effect of variables on the structure of nonwovens and absorbency related properties, sample's characteristics such as thickness and mass density were measured. The absorptive capacity method was carried out by an arrangement. Carded webs from polyester fibers and viscous fibers of four different basis weights (35 g/m^2, 40 g/m^2, 45 g/m^2 and 50g/m^2) were hydroentangled using three different water jet pressures (50 bar, 60 bar and 70 bar). Sample thickness was measured according to ASTM D 5729-97 test method, with a Shirley digital thickness tester. Water vapor permeability was measured by cup method according to BS 7209 in which eight samples were measured and the mean value was recorded. In their study, it was showed that the water jet pressure and basis weight by changing hydroentangling energy, were effective parameters on entangling of fibers and nonwoven structure and properties such as mass density, thickness and capillary pore size. It was observed that increasing weight leads to the increase of thickness and mass density. Moreover, it was caused a decreasing trend in water vapor permeability and water retention. On the other hand, by increasing water jet pressure, the thickness, water retention and water vapor permeability decreased whereas the mass density increased [11].

Unal [12] developed a new disposable and antibacterial sheet. By utilizing this product, it was targeted to partially prevent spread of the infections in the hospitals. The product would be disposable, thus cost of the material was highly important. Because of that the product was designed as polypropylene and spun bonded nonwoven. New disposable nonwoven sheets to prevent hospital infections aimed to develop three types of materials were used in it.

The produced structures and showed very good antibacterial the use of both patients and visitors and seen to be useful in terms of employee health result of tests applied to fabrics, thin and nonwoven structures (resistance lower than conventional woven sheets) due to the tensile shear strengths are low, but it is designed as a single-use buildings that were not create a significant disadvantage. It also structures abrasion resistance, wet, is sufficient to use properties such as softness observed in experimental studies [12].

Stahl [13] studied the possibility of bonding T-800 nonwoven fabric with hydroentangling. This fabric is traditionally calendared and thermally bonded to produce various fabrics known as Tyvek. The hydroentangling process fibrillates the T-800 fibers producing a stronger and more open structure. Hydroentangling has proven to be a viable bonding process for T-800 un-bonded Tyvek as an alternative to thermal calendaring. A greater understanding of un-bonded T-800 fabric was achieved with mechanical properties testing and SEM analysis. The studies of the relationship of specific energy to the threshold properties of Tyvek confirmed the results of previous studies and inspired a greater understanding of the effect of the interaction of energy and energy absorbency on the hydroentangling of nonwoven fabrics [13].

Zheng [14] focused on establishing fundamental relationships between fiber properties, water jet properties, forming wire geometry, and fabric properties. First of all, various types of fibers and forming wires were chosen based on their properties and used to make hydroentanglement fabrics at the Nonwovens Laboratory at College of Textiles, North Carolina State University (NCSU). Then fabric properties were measured. Four different types of poly (ethyleneterephthalate) (PET) Poly-(trimethylene terephthalate) (PTT), Nylon 6, Nylon 6. 6, Polypropylene (PP) was used in this study. Experimental trials were conducted using different fibers with range of properties, forming wires, and water jet pressure. Fabric tensile strength was used as an indicator of degree of hydroentanglement to assess the fabric performance. The results showed that the hydroentangled fabric tensile strength was significantly influenced by forming wire type, fiber properties, and jet pressure. Three force mechanisms (flexural rigidity, friction force, and strain force) were analyzed to reveal which force is more significance in governing fabric strength [14].

Malshe [15] studied on characterize the effects of plasma pretreatment on hydroentangling efficiency in terms of fabric mechanical and electrostatic properties. Characterization data for the untreated and plasma treated webs was analyzed to establish a trend between the plasma treatment and the substrates response to it. In previous works by other research groups, water pooling problem had been reported when hydroentangling hydrophobic fibers such as polypropylene. The focus of this work was to eliminate the problem via atmospheric plasma treatment prior to hydroentangling. The purpose of this study was to determine the effects of atmospheric plasma pre-treatment on nonwoven webs due to plasma induced hydrophilicity and other surface modifications such as roughness/smoothness. Different fiber substrates were treated with atmospheric plasma in a continuous run and hydroentangled at different time's post-plasma treatment to determine the effect of aging on hydroentangling efficiency [15].

Kennerly [16] researched hydroentangling woven jacquard base fabrics using several speed and pressure combinations to mechanically enhance the structure. It also proposed to hydroentangled a loose web of fibers onto a woven jacquard fabric as a form of mechanically bonding the two structures. By bonding these fibers onto the woven fabric, the structure would be stabilized and mechanical properties would be enhanced. Control fabrics were compared to hydroentangled samples in order to select optimal hydroentangling processing parameters. The effects of these process parameters on fabric properties were studied. The mechanical properties of the woven fabrics before and after hydroentangling were also assessed. One objective of this research was to determine if hydroentangling was a feasible means to overcome certain physical and mechanical shortcomings of jacquard woven fabrics. Test data indicated that certain aspects would be improved, while others might be negatively impacted by hydroentangling. There were also critical energy points where any further enhancement in properties was diminished. The end use application of the fabric, as well as performance criteria would play a key role in determining if hydro entangling could be used as an alternate means of finishing a jacquard woven fabric, and would be unique to the specific company and production capabilities. A second objective of this research was to determine if hydroentangling was a feasible means of bonding a single fiber carded web onto a base jacquard woven fabric. With the correct combination of base fabric construction and specific energy, bonding was possible. When energy was too high, the design would be jeopardized, while if energy was too low, adequate entanglement would not happen. Test data indicated that certain properties would be improved, while others might be negatively impacted by hydroentangling. The end use application of the fabric, as well as performance criteria would play a key role in determining if hydroentangling could be used as a feasible means of bonding a jacquard woven fabric with a carded web, and would be unique to the specific company and production capabilities [16].

Begenir [17] observed the role of the nozzle geometry in the characteristics of hydroentangling water jets. Three different conventional sharp-edge nozzle geometries, so-called cone-up, cone-down and cylindrical, under different pressures below 3500 psi was examined. To exploit aforementioned nozzles, a single-water jet test stand capable of working under manifold pressures up to 5000 psi was designed and built. Profiles of the water jets produced by each of these nozzles were visualized by using a Nikon D1x digital camera and a regular light. The breakup lengths and the spray angles of the water jets were extracted from the captured images by utilizing image analysis techniques and were compared with each other under different operating conditions. It was revealed that the cone-up nozzle produces water jets with considerably shorter intact lengths and slightly larger spray angles compared to the two other geometries considered. This distinct behavior was attributed to the cavitations-induced turbulence inside the cone-up nozzles. Discharge coefficients of the above nozzles were also measured versus injection pressures and showed a higher discharge coefficient for the cone-up nozzle compared to the others. The reason underlying these findings was attributed to the formation of the constricted water jet in the cone-down and cylindrical nozzles [17].

Even though there are many articles and thesis published about nonwoven industry in textile database, spunlace (hydroentangling) has been published very few sources in the scientific literature in the area especially, investigation of performance properties of spunlace nonwoven fabrics produced polyester and viscose fibers. This situation can be explained to the fact that spunlace fabric producers are supposed the information confidential.

CHAPTER 2

NONWOVEN FABRICS

2.1 Introduction

Today's nonwovens can be called engineered fabrics. They provide specific functions such as absorbency, liquid repellency, resilience, stretch, softness, strength, flame retardant, wash ability, cushioning, filtering, bacterial barrier and sterility. Nonwoven fabrics are created for specific end-uses, while achieving a good balance between product use-life and cost. Fabricated or converted nonwoven products use nonwoven fabric as a raw material. Such products include diapers, sanitary napkins, wipes and surgical packs and gowns. Sales volume figures reported for converted products are based on the value of the fully fabricated product at the end-user level, e.g. the retail level in the case of consumer products and the hospital level in the case of surgical products. For example, the manufacturer s-level value of nonwoven cover stock in disposable diapers is often only 10-15% of the retail sales value of the diapers [18].

Nonwoven products in disposable applications are those which discarded after a single use (e.g. a diaper) or after only a few uses (e.g. a wiping cloth). Nonwoven products in durable applications are those incorporated into other products which are used continuously (e.g. the interlining in a dress, geo textiles or the backing for carpet) [18]. Nonwoven products have gained user acceptance because of performance advantages such as the added convenience of disposable diapers, the improvement in aseptic technique made possible by nonwoven surgical packs and gowns and the mold ability of nonwovens used to make automotive carpet. Nonwovens satisfy many of the ever-increasing needs of industrialized economies. The use of nonwoven fabrics makes possible the production of convenient, functional products for societies where the desire for convenience seems limitless [18].

Nonwoven fabrics can be flat or lofty, porous sheets that are made directly from separate fibers or from molten plastic or from plastic film. The definition of nonwoven fabrics follows this section. Although they resemble textiles, they are not made by weaving or knitting. Nonwoven processes can manufacture fabric at many hundreds of feet per minute (or in a few cases a thousand feet per minute) compared to only a few feet per minute for conventional knitted or woven textiles. Nonwoven fabric weights can range from less than 1 ounce/ square yard to as high as several hundred ounces/square yard. They can be paper thin or even gossamer-like. They can mimic the appearance, texture and strength of a woven fabric and can be as bulky as the thickest padding. The various processes provide a spectrum of products with diverse properties. Nonwovens are generally accepted by market analysts, government, statisticians and textile groups worldwide as a distinct class of products with important uses and functions [18].

In recent years, many new nonwoven-making technologies have been developed. Advances in man-made fibers, plastics and additives have been combined with process research and machinery development to open the way to new and important products. These developments have led to new fabric structures with valuable and marketable properties. New fibers, finishes and binders have been developed specifically for nonwovens. Efficient equipment designed to manufacture advanced nonwovens at high speeds has emerged. Equally impressive is the high speed equipment that dye, print, emboss, crimp and convert rolls goods into end-use products**.**

A few of the major techniques used to make nonwovens are listed below:

Carded thermal bonded and resin bonded staple - fabrics formed by processing textile staple fibers over a card and bonding by resin or thermal means.

Needle punched staple fabrics formed by processing staple fibers over a card or other web forming device and entangling the fibers by penetrating the fabric with needles.

Air laid - fabrics formed by air laying and bonding pulp and/or staples.

Wet laid - fabrics that contain long (longer than pulp) fibers and are made by papermaking techniques.

Spun bonded - fabrics formed by in-line melt extrusion spinning of filaments.

Melt blown - fabrics formed by in-line melt extrusion spinning of very fine fiber diameter, less than one denier.
Spunlaced or hydroentangled - fabrics formed by carding, air laying or other web forming techniques and consolidated by hydraulic needling.
Laminates - combinations of nonwovens, scrims, fibers, films, foams or tissue.
Porous film - fabric-like webs made by forming a plurality of apertures in plastic film [18].

2.2 Worldwide Nonwoven Fabrics

Nonwovens are a global industry with estimated worldwide consumption approaching 5 billion pounds. Volume growth exceeds 6% per year and is expected to reach about 7 billion pounds by 2003. The three major developed markets - North America, Western Europe and Japan - account for just under 75% of the worldwide roll goods market. The growth rates in nonwoven consumption vary significantly by region. Rapid demand growth has emerged in several developing markets in the Pacific countries and, more recently, in Latin America. These new geographic markets at the beginning of the 21st century are, expected to account for a third of the global demand [18].

The international trade of nonwoven fabrics is steadily increasing. The leading nonwovens producers participate in the industry on a global basis. These competitors benefit from growth, technology leverage and enhanced understanding of end-user needs. In developing countries, local firms are entering the nonwovens business by acquiring technology through the purchase of turnkey, typically compact, production lines or by forming joint ventures with multinational partners. One of the major attractions of the nonwoven products business to many companies is its worldwide growth potential. Globalization accelerates over the next decade, and global economic power likely shift eastward: Europe, Japan, and the United States will experience relatively slow growth, while Asian economies grow faster. With global markets in low-and middle-income countries becoming the world’s largest consumer markets, the demand will likely increase for all nonwoven products. One can expect boom in agricultural and construction nonwovens, as well as further growth of low-impact consumer and hygiene products. Overall, consumers develop increasingly higher expectations with the development of information technologies worldwide; access to information is heightening global awareness of risks and favor consumer-driven regulation. As a consequence, the increasingly global nonwovens market is likely to become polarized between two types of product. Many mass-produced ones targeting the global middle class will remain high-volume, with profit margins under pressure. In contrast, some increasingly tailored high-tech products for customers in high-income countries will be manufactured in relatively low volumes, usually with a higher value added. In both cases, a low environmental impact is the object of increased attention and requires innovative solutions [19]. Nonwoven industries can be used plenty of countries all over the world, there is a Figure shown in Figure 2.1 which gives information about the world production industry all over the world, according to belonging to 2013 statistics Europe is much more production are than other huge country such as South America, North America, Japan, and China.

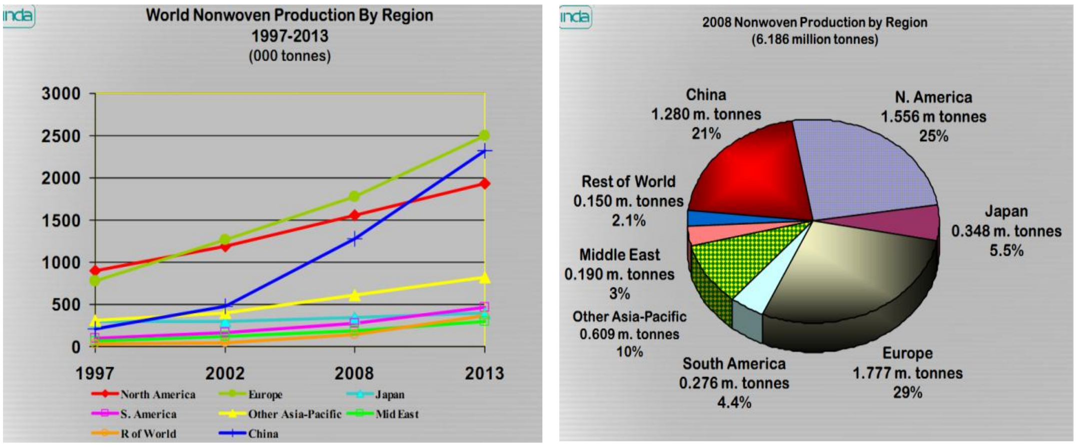

Figure 2.1. Overlook for production of nonwoven industry in the world [20]

Figure 2.2 shows that mainly four different production methods in nonwoven industry, spunlaid is one of the highest production methods compare to other Carded, Air Laid and Wait Laid production system. According to specification of Spun Carded bonding technology needle punch is much more production amount than Spunlace and Thermal system shown in Figure 2.3 but Spunlace is increasing slightly compare with needle punch system, for this reason we can predict that after ten years Spunlace might be the lead of carded production technology.

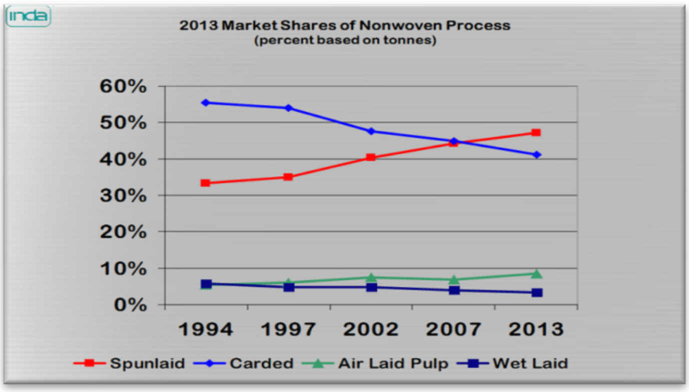

Figure 2.2 2013 World nonwoven production process [20]

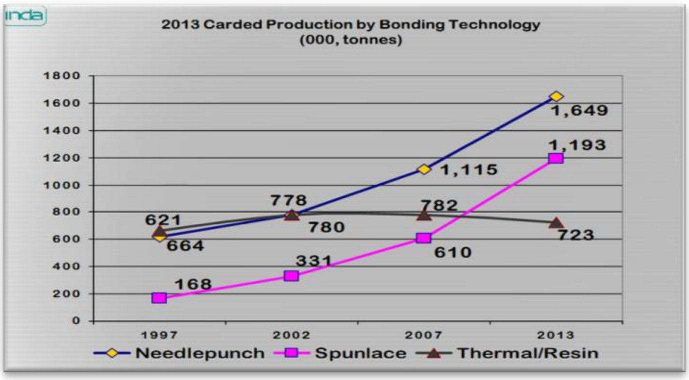

Figure 2.3. Carded productions by bonding technology [20]

According to 2008 data spunlaid production system is getting bigger than other process shown in Figure 2.4. There is a big competition spunlaid and carded system, other system air laid and wet laid are hard to see catch up the pioneer spunlaid or carded system. According to comparison of using area of Nonwoven product hygiene is the hugest percentage represented in Figure 2.5 other products are wipes and construction behind of hygiene ratio Figure 2.6 shows nonwoven goods production in term of tone.

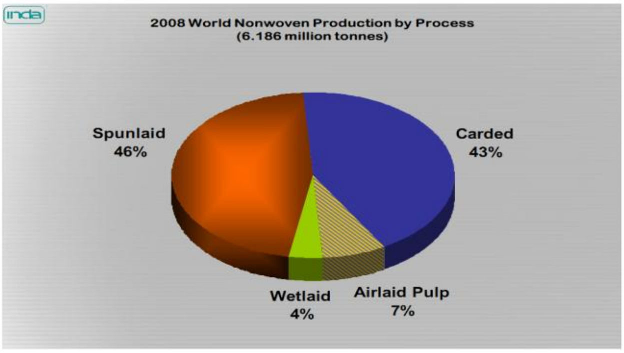

Figure 2.4. Market shares of nonwoven process [20]

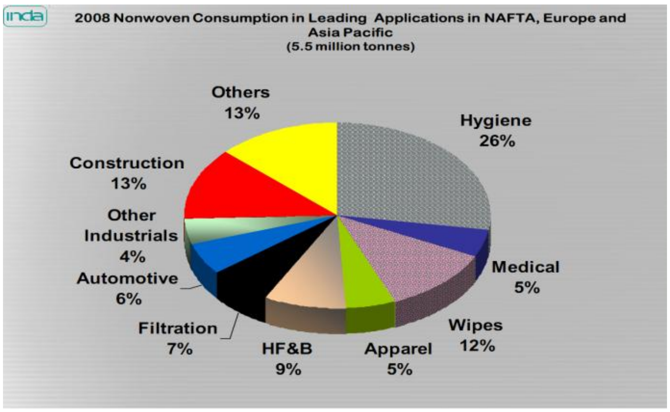

Figure 2.5. Nonwoven production lists [20]

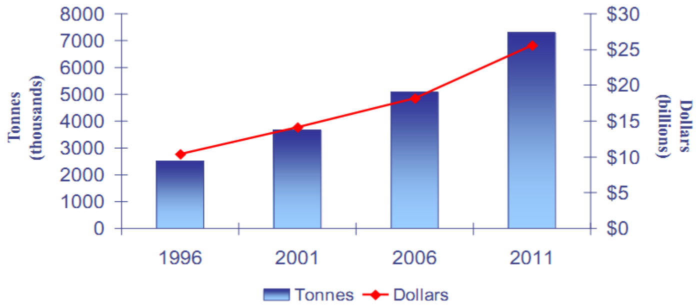

Figure 2.6. World nonwovens roll goods [20]

2.3. Nonwoven Fabric and Fibers used in Areas

Nonwovens are innovative, high-technology fabrics engineered from fibers to exhibit specific properties (absorb liquids, retard flames, contain bacteria, etc.) and used across a wide range of applications and products, both at home and at work. In fact, nonwovens are so versatile and widespread that they are defined by what they are not they are sheets of any type of filament, formed into a web and bonded together by any means, but not woven or knitted. Used alone or combined to other materials; they are found in products without which we can no longer imagine living. As surgical gowns, they protect both patients and surgeons from infections. They make filters of well-define properties, be it for a single-use tea bag or for a durable allergen barrier. In their less visible uses, they stabilize soils, control erosion, protect crops against insects, or selectively adsorb oil spills. Nonwovens as consumers know them are the end products of a value chain that starts with the raw materials (currently, mostly oil for synthetic fibers and wood for cellulose fiber. The fibers, which need not be spun in yarns, are entangled into a web and bonded mechanically, thermally, or chemically. These bonded webs are typically produced in sheets or rolls, which eventually enter the fabrication of consumer products. Non-woven fabrics, with a growth rate recorded in recent years, started to build up a significant portion of the textile and apparel industry. Non-woven fabrics in the textile industry are the most dynamic and the most promising area. Day by day new products in this area, new processes, and new materials are produced and offered to the market. The discovery of new products, nonwoven fabrics, and traditional products and materials to meet the new requirements due to the substitution has the potential to be of great use. Nonwovens offer maximized levels of safety and hygiene. They are used in adhesive plasters, wound pads and compresses, orthopedic wadding's and stoma products. The nonwovens used here must. For example, be particularly absorbent and air-permeable, must not stick to the wound, and also have to ensure a skin-friendly micro-climate [19, 20, 24].

Table 2.1. List of used in areas [21]

Personal care and hygiene	**Clothing**
Baby diapers Sanitary napkins Products for adult incontinence Dry and wet napkins Cosmetic wipes Breath-aiding nose strips Adhesives for dental prosthesis	Components for bags, shoes and belts Insulating materials for protective wear Outfits for fire protection High visibility clothing Safety helmets and industrial shoes One-way work clothing Clothing and shoe bag
Medical use	**Leisure and travel**
Caps, gowns, masks and overshoes for operating rooms Curtains and blankets Sponges, bandages and tampons Bed linen Pollution-controlled gowns	Sleeping bags Suitcases, handbags and shopping bags Containers for food transport Vehicle headrests CD slipcases Pillowcases
Agriculture	**Geo-textiles**
Covers for greenhouses and cultivations Protections for seeds and roots Fabrics for pests dominance Pots for biodegradable plants Materials for capillary irrigation	Covers for road asphalting Soil stabilization Drainage Sedimentation and erosion control Water-hole sheathings
Building industry	
Insulation for roofs and tiles Thermal and acoustic insulation Boards for walls and false ceilings	Claddings for tubes Casts for concrete Stabilization of soils and foundations
Disposable cloths for industrial uses	
Manufacturing, mechanical and maintenance industry Machinery and equipment cleaning Sorbents for fluid and oil	**Car industry** Surface preparation before Varnishing Polishing Sorbents for oil and chemical substances

Table 2.2. Nonwoven fabric fiber usage tables [2]

FIBERS	RESULTANT PROPERTY	
	POSITIVE	NAGETIVE
POLYESTER	• Good recovery • Good Heat setting property • High elasticity • Good drape • High wet strength	• High pilling tendency • Formulation of static charge
ACETATE FILAMENTS	• Good handle • No pilling • Good recovery • Good drape • Easy bonding • Low price	• Low wet strength • Low abrasion resistance • Low softening point
POLYAMIDE	• Good wet strength • Good resistance to soiling • Quick drying • Good chemical resistance • Good elasticity • Good heat pocessability	• Bad handle • Bad light fastness • High pilling tendency • High price
VISCOSE FILAMENTS	• Good strength • High bulk • Good drape • No pilling • Easy cleaning • Low price	• Low wet strength • Low abrasion resistance • Slow drying • Hard hendle
POLYACRYLONITRILE	• Good recovery • Good drape • Excellent chemical resistance • Soft hand • High bulk • Good moisture resistance • Excellent sun light fastness	• Low abrasion resistance • Tendency to pilling • High price
COTTON	• Good abrasion resistance • Good bulk • High wet strength • Soft handle • Easy bonding • Excellent absorption power • Low price	• Non elastic recovery • Low resistance to soiling • Low uniformity of fibers
WOOL	• Good bulk • High elasticity • Soft, warm handle • Quick recovery • Good absorption power	• Tendency to pilling • Low abrasion resistance • High shrinkage • Low strength • Unstable price

2.4. Classification Nonwoven

According to raw material, Nonwoven is divided as it is shown Figure 2.7.

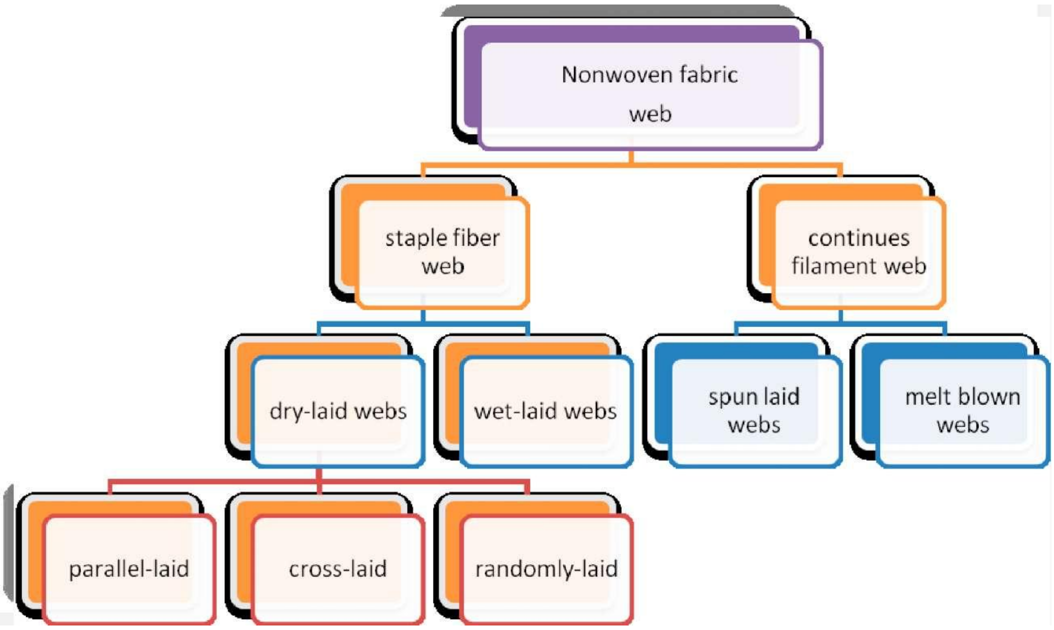

Figure 2.7. The classification of nonwovens [2]

2.4.1 Staple Fiber Webs

a. Wet-Laid Webs

The wet-laid web forming technique is similar to paper making technique. The fibers are dispersed in water and then laid on a wire mesh to filter the liquid and form web, which is transferred to a drying Felt before finally being heat cured in a continues process seen in Figure 2.8. This produces a web in which fibers are randomly oriented. These webs are then superimposed on one another in a parallel fashion; hence it is termed as wet-laid parallel-laid webs. It is the combing of the web that is directional, not the fibers within each web [2].

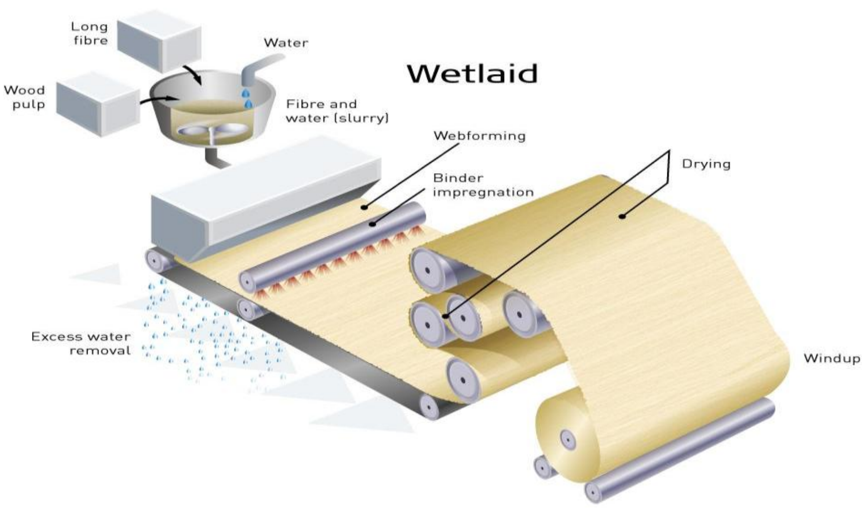

Figure 2.8. Principle of wet laid web formation [22]

b. Dry-Laid Webs:

Dry laid webs shown in Figure 2.9 are mainly produced using staple fibers, natural or manmade. The dry-laid process web is produced from staple fibers Production takes place in a carding machine fitted with rotating rollers

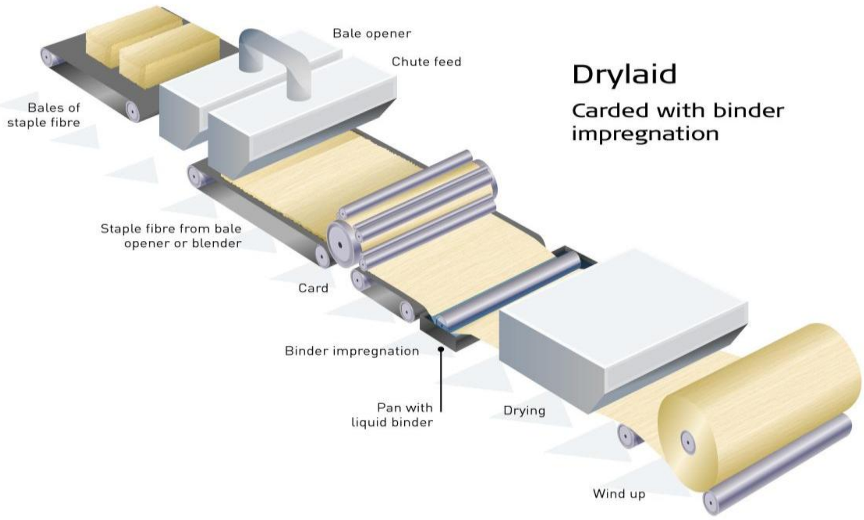

Figure 2.9. Principle of dry laid web formation [22]

Here are mainly three types of web laying techniques or dry-laid webs.

- Parallel laid webs
- Cross laid webs
- Randomly laid webs or air laid webs

i. Parallel laid webs

Several carding machines are placed one behind another in a long line. The web from the first card is allowed to fall on a conveyor which runs along the full length of the production line underneath the cards. As the web from the first card passes from the second card, the web from second card is superimposed upon it. This process is repeated along the line until a nonwoven fabric of the correct mass per unit area is achieved. In this study the spunlace is produced by parallel laid web technique.

ii. Cross laid webs

The cross laying, the web deposited on an inclined lattice as it leaves the card and is subsequently laid in cross wise manner on a wider lattice which is moving in a direction at right angle to the original direction of laying. This cross layer enables three important characteristics of resulting nonwoven fabric to be controlled.

- ✓ The width of the fabric, with cross laid nonwoven fabric of up to the meters in width being possible.
- ✓ The mass per unit area of the nonwoven fabric, which is dependent on the take up speed, so that slow take off allows many layers to be superimposed and produce heavy fabrics, while fast take off produces fewer layers and a more open zigzag of lay to create lighter fabrics
- ✓ The strength characteristics of the nonwoven fabric as cross direction than in the machine direction though the ratio can be varied by altering the angle of lay and the subsequent drafting of the cross laid nonwoven fabric.

By stretching the cross laid webs the ratio of strengths of the fabric in the machine and cross directions can be controlled to suit the requirements of the end product [2]. The cross lapper is thus capable of producing light to heavy fabric weights with balanced MD/CD strength ratios and allows the production of needled felts with low to high elongation percentages and with high tensile strength values [23].

iii. Randomly laid webs or air laid webs

In alternative means of producing nonwoven fabrics is offered by machines using aerodynamic feed of the fibers. In this case, those fibers from a carding cylinder are carried in air currents and deposited onto a condenser cage, from which they are drawn off in sheet form. The condenser cage is usually a hollow cylinder formed from a mesh.

The air or random laying techniques allows fabrics with a wide range of mass per unit area to be produced, in which fiber orientation can be made very much more random than is the case with traditional web layering. Short fibers can be processed easily, allowing textile waste materials to be used in nonwovens [2].

2.4.2. Continuous Filament Webs

There are mainly two types of continuous filament webs.

a. Spun-laid webs b. Melt blown webs

a. Spun-Laid Webs

In this technique (seen in Figure 2.10), a melt solution of a fiber forming polymer is extruded through a systems of spinnerets in a high velocity current of air or other gas. The support than carries the web to a bonding stage where Consolidation of web occurs. Spun laid fabrics tend to have low bulk and high tensile and tearing strength. This leads to numerous industrial applications such as protective clothing, filters, packaging and geo textiles. Spun laid fabrics tend to have low bulk and high tensile and tearing strength. This leads to numerous industrial applications such as protective clothing, filters, packaging and geo textiles [2].

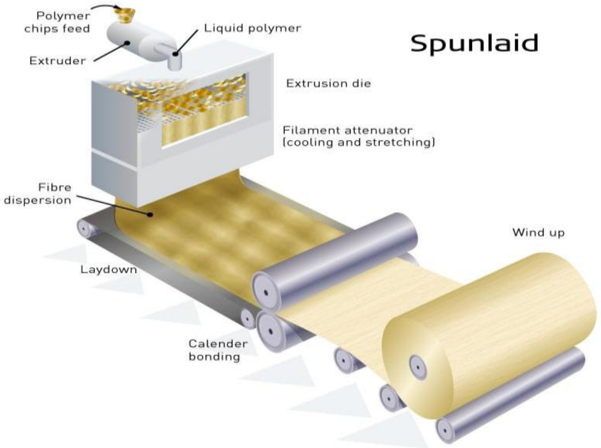

Figure 2.10. Principle of spun laid and melt blown web formation [22]

b. Melt Blown Webs

These are produced initially in the same manner as spun-laid webs. With polymer extruded through the holes in a spinneret into a high velocity current of air. The difference between these two methods is an increased force used the current which breaks the filaments rather than just drawing them to produce staple fibers web [2].

2.5. Nonwoven Fabric Bonding Techniques

Webs, other than spunlaid, have little strength in their unbounded form. The web must therefore be consolidated in some way. This is affected by bonding, a vital step in the production of nonwovens. The choice of method is at least as important to ultimate functional properties as the type of fiber in the web [24]. In general, there are three basic types of nonwoven fabric bonding techniques. These are chemical, thermal and mechanical shown in Figure 2.11.

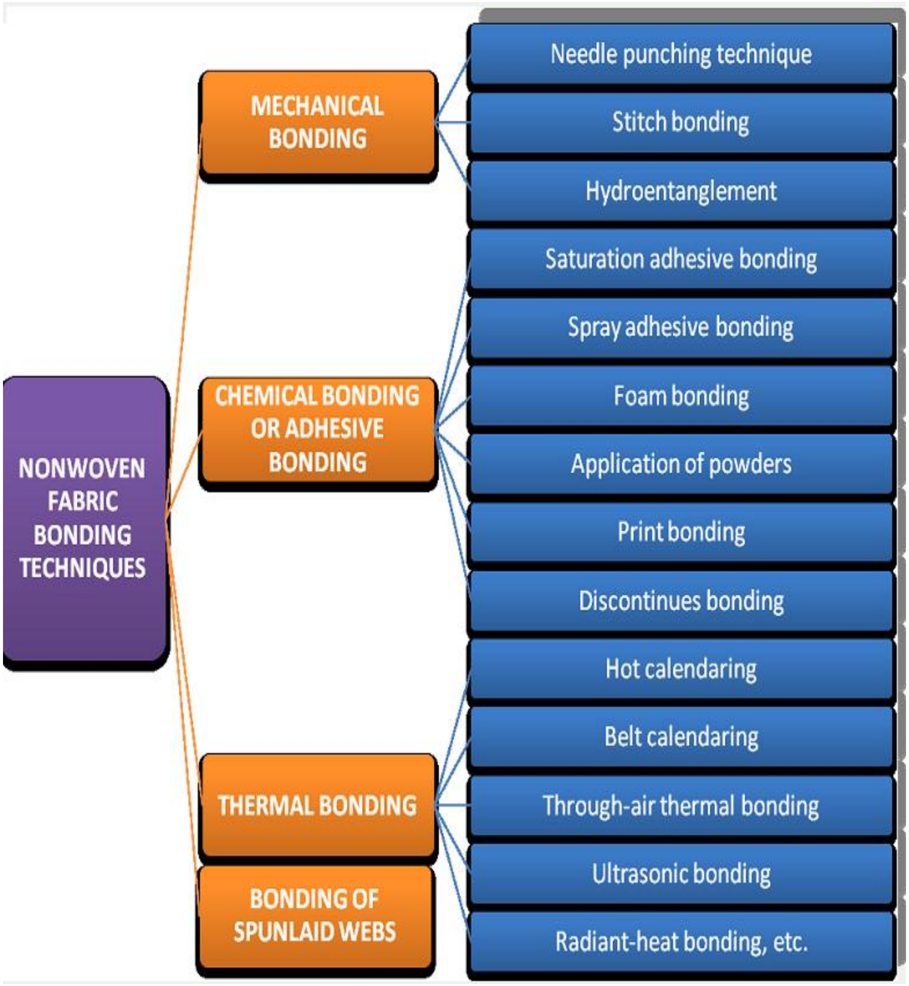

Figure 2.11. Nonwoven fabric bounding technique [2]

2.5.1. Chemical bonding

Chemical bonding seen in Figure 2.12 mainly refers to the application of a liquid based bonding agent to the web three groups of materials are commonly used as binders-acrylate polymers and copolymers, styrene-butadiene copolymers and vinyl acetate ethylene copolymers. Water based binder systems are the most widely used but powdered adhesives, foam and in some cases organic solvent solutions are also found. There are many ways of applying the binder. It can be applied uniformly by impregnating, coating or spraying or intermittently, as in print bonding. Print bonding is used when specific patterns are required and where it is necessary to have the majority of fibers free of binder for functional reasons [4].

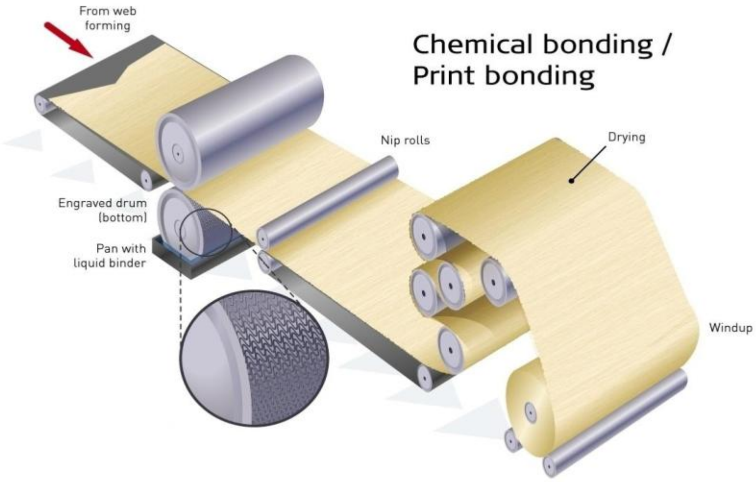

Figure 2.12. Chemical bonding technologies [4]

2.5.2. Thermal bonding (cohesion bonding)

This method shown in Figure 2.13 uses the thermoplastic properties of certain synthetic fibers to form bonds under controlled heating. In some cases the web fiber itself can be used, but more often a low melt fiber or bi component fiber is introduced at the web formation stage to perform the binding function later in the process

<u>There are several thermal bonding systems in use:</u>

- Calendaring uses heat and high pressure applied through rollers to weld the fiber webs together at speed,
- Drum and blanket systems apply pressure and heat to make products of average bulk,
- Sonic bonding takes place when the molecules of the fibers held under a pattern are excited by high frequency energy which produces internal heating and softening of the fibers [24].

2.5.3. Mechanical Bonding

The term mechanical bonding is taken to mean the bonding together of fibers in the web either by felting or fulling, using pressure, heat, moisture and mechanically or by using needles and the jets of air and water. The webs can also be reinforced by working in threads or fabric e.g. layer of threads woven or knitted fabrics or film [2].

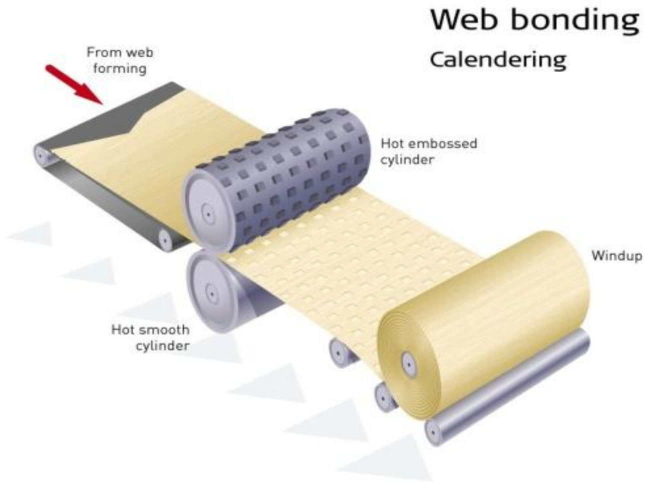

Figure 2.13. Thermal bonding technologies [24]

2.5.3.1. Needle punching technology

Needle punching shown in Figure 2.14 is the oldest method of producing nonwoven products.

- Unique physical property i.e. elongation in all (x, y, &z) directions for mould able applications.
- Ability to attach layers of different types of fiber webs to produce composites
- High opacity per unit area and high strength makes them overwhelming choice for geo textiles fabrics [4].

Figure 2.14. Needle punching technology [24]

2.5.3.2. Spun-Laced Technology

Spunlace is seen in Figure 2.15 inspired from needle punching, is a process capable of bonding loose fibers into a uniform web, by means of spaced high velocity jets of water are used to mechanically interlock fibers and fiber bundles to create fabrics. The energy is supplied by high-pressure streams of water in the form of columnar jets. The impact of the energy from the jets of water displaces each individual fiber and rearranges the fiber in respect to neighboring fibers. During displacement, fibers twist around one another, or interlock, due to frictional forces. The resultant fabric is a compressed and uniform web of entangled fibers [16].

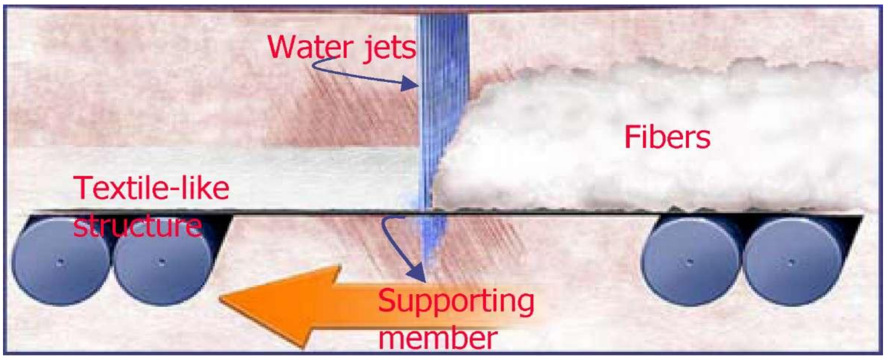

Figure 2.15. Spunlace technologies [16]

2.6 Spunlace (Hydroentanglement) Bonding Technology

Spunlace or hydroentanglement is web bonding technology, which uses fine, high pressure jets of water to cause the fibers to interlace. Water jet due to high kinetic energy reorientates fibers according to the shape of the support screen (sieve belt or perforated drum). As a bonded web is possible to use whole range of nonwovens: carded webs, spunbond and meltblown webs, wetlaid, airlaid and composites. Binding point is a set of fibers with various orientations, which are bonded by friction forces (similar as for needlepunch process). Figure 2.16 shows spunlace process. At first is fibrous web preweted to eliminate air pockets. The thin water bundle goes from the jets through the fibrous web and support screen (one hydroentanglement unit). To obtain better bonding efficiency is water sucked from the opposite side of the support screen. Then is water purified and returned to the jet manifold. The structure of the bonded textile depends on the adjustment of water jets and structure of the support screen. It is possible (and often used) to repeat several spunlace units. The pressure of water jets gradually increases [26].

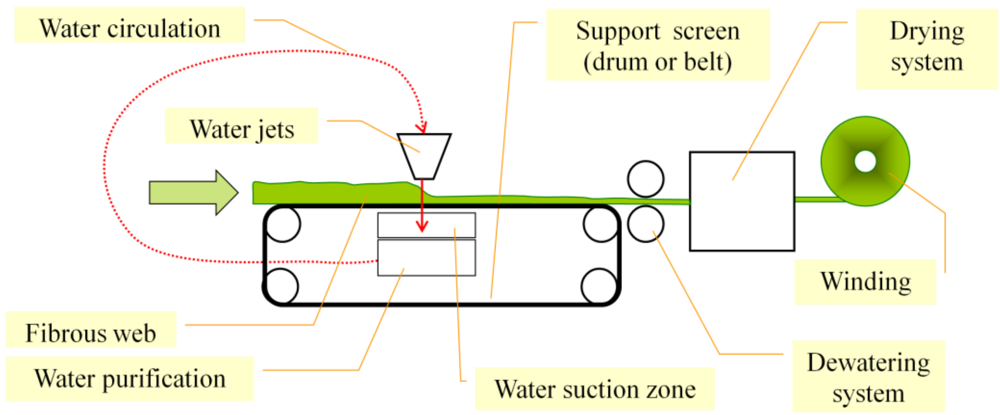

Figure 2.16. Spunlace (Hydroentanglement) process [27]

Main features of Spunlace (Hydroentanglement) textiles

- ✓ very good textile drape (low stiffness) and very soft handle
- ✓ no chemical or melt binders; it is possible to prepare 100 % natural fibers, suitable for sanitary products, suitable to recycling
- ✓ wide range of textile area surface: from 10 to 1000 g/m^2 and higher density (g/m^3) than for needle punch textiles
- ✓ Strength is much higher than after mechanical needling (for the some area weight); similar to woven textiles
- ✓ wide range of textile structure (depending especially on the perforated belt structure) – wide range of textile properties
- ✓ uniform surface due to more fine interlacing of fibers (compared with needling)
- ✓ very high textile production: up to 300 m/min for carded and air laid webs and up to 500 m/min for wetlaid and spunbond (meltblown); textile width up to 6000 mm [26].

2.6.1 Fibers used in Spunlace Nonwoven

Spunlace materials are also made of all fibers, which can be a blend of two fibers, such as polyester and rayon, or 100% of one type of fiber. The fibers can be natural or synthetic. The most common fiber used is polyester. Polyester spunlace fabrics are used as coating substrates, interlinings, roofing substrates, bedding materials and in some other durable markets an advantage of polyester is its strength and capability. Blends of two or more fibers are, by far, the most common form of spunlace materials as composite fabrics share the physical attributes of their component fibers. Rayon and polyester, often in a 50/50 60/40 or 70/30 ratios are very common.

Rayon adds softness and its hydrophilic property holds moisture, while polyester adds strength and durability properties. Rayon/ polyester blends are widely used in wipes where absorbency, low linting, strength, softness and textile-feel are required. All rayon spunlaced materials or blends with a small amount of polyester are used to make gauze replacements, surgical sponges and bandages.

Cotton is a favored fiber with a good reputation. It is found in medical products and some oshibori wipes (used prior to dining) in Japan are made of spunlace cotton. The spunlace technology is capable of bonding a variety of natural and synthetic fibers. The end-markets and physical requirements of the spunlace material will determine the type of fibers best suited for selection. The physical and aesthetic properties of the finished material can also be influenced by the degree of the spunlace process and the selection of the fibers. Just about any fiber can be spunlace as long as they fall within the minimum and maximum fiber lengths. Several principal fibers used, either alone or in blends, are provided with the main end as shown in Table 2.3 [28].

Table 2.3. Fibers properties and used in markets [28]

Fibers, Properties and End Markets

Fiber	Fiber Properties	Usual End Markets
Cotton	Cellulosic fiber: absorbent, soft, bulky, flexible and dyeable. Good consumer image.	Medical dressings and sponges, wipes
Lyocell	Cellulosic fiber: absorbent, biodegradable; relatively strong and fibrillates with entangling; good wet strength, good draping.	Medical dressing and sponges, wipes
Rayon	Cellulosic fiber: absorbent, softness, drapability, hydrophilic	Medical dressings and sponges, wipes
Polyester	Versatile fiber, good chemical and moisture resistance; strength; heat resistance; thermoplastic fiber, moldability with heat; wrinkle resistance	Blending fiber to add strength. Apparel; artificial leather; bedding; automotive; home furnishings
Polypropylene	Moderate cost fiber; strength; good chemical, moisture and UV resistance; thermal plastic fiber	Automotive interiors; absorbent hygiene products
Wood Pulp	Cellulosic fiber: absorbent, low cost; opaque; dyeable	Wipes, disposable apparel

2.6.2 Spunlace (Hydroentanglement) Machine

Spunlace nonwovens are mainly used in hygiene and medical applications that require a very fine and gentle surface, also in many other fields, such like filtration, artificial leather, automotive. It offers greatest flexibility to choose nearly any blend of raw materials, from natural to synthetic fibers, without the use of chemical binders [19]. Here are described four main parts of spunlace machine shown in Figure 2.17 water jets, perforated drum (sieve belt), water purification system and drying system.

Figure 2.17. Spunlace (Hydroentanglement) [47]

a. Water jets:

Water jets sen in Figure 2.18 are ordered to a jet manifold, which is made from stainless steel plate with holes. *Parameters of water jets:*

- ✓ Density of jets: 10 – 30 jets/cm
- ✓ Jet diameter: 80 – 800 μm
- ✓ Pressure inside the jet manifold:
- ✓ up to 60 MPa for web bonding (Fleissner)
- ✓ up to 25 MPa for web patterning (Perfojet)
- ✓ velocity of water jet 10 – 350 m/sec

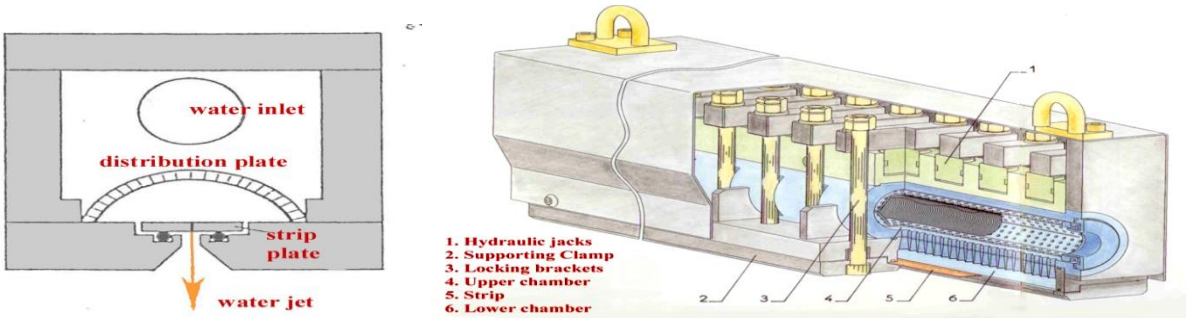

Figure 2.18. Water jet [26]

b.Support screen (drum or sieve belt)

Support screen has two main purposes: at first to hold fibrous material to obtain reorientation and interlacing of the fibers and at second to determine the final structure of the bonded textile. Figure 2.19 shows examples of support screens. Support screen used for web bonding is made from the bronze or synthetic sieve. The typical range of the sieve wire diameter is 10 – 130 μm. The size of sieve mesh must be precisely defined. The sieve mesh is possible define as an area closed by wires, which depends on the wires diameters and distances. The typical closed area is from 0.012 to 0.5. To obtain more efficient bonding process the water is sucked from the opposite side of the support screen.

Support screen used for web patterning is made from finer sieve. Mostly it is perforated drum seen in Figure 2.20. Where the pattern shown in Figure 2.21 is made by photographic transfer technique [26].

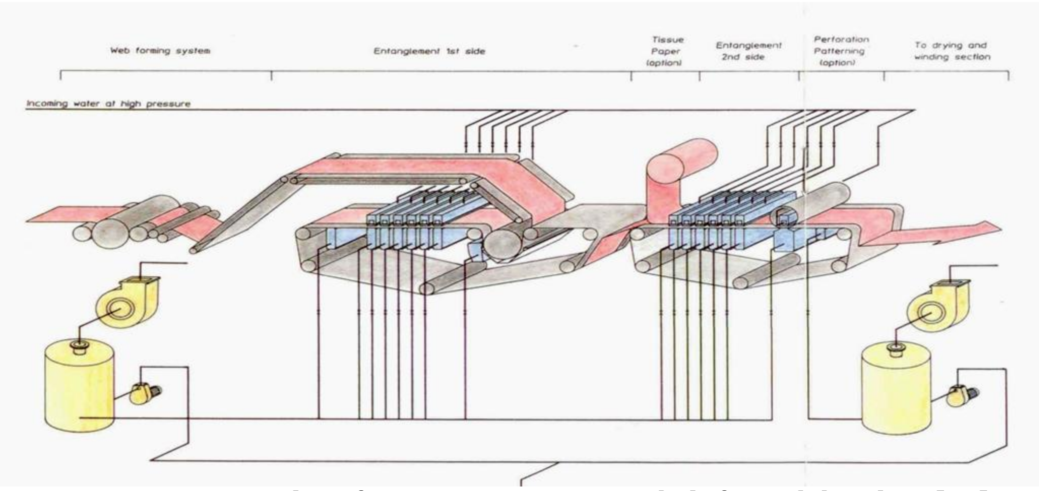

Figure 2.19. Examples of support screens: sieve belt for web bonding [26]

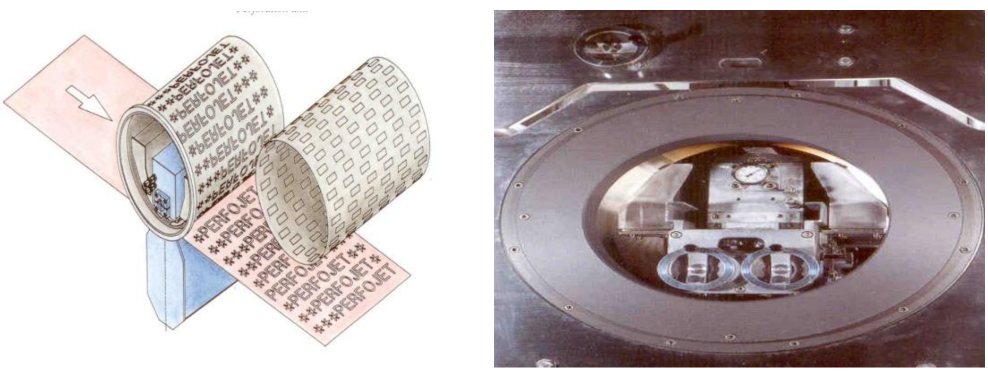

Figure 2.20. Examples of perforated drums used for patterning [26]

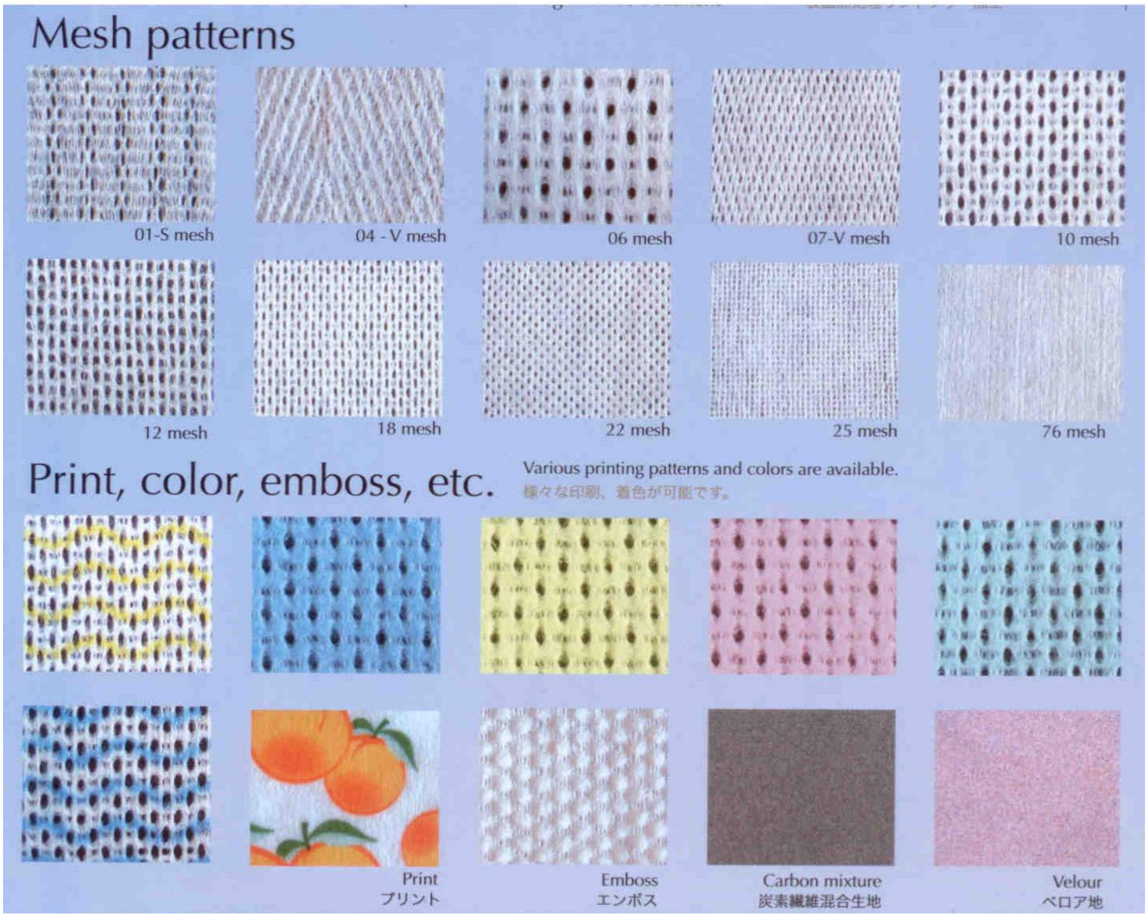

Figure 2.21. Examples of spunlace patterns [26]

c. Water suction system:

Figure 2.22 represents water suction system. The kinetic energy of the water jet is dissipated on the support screen surface. Thus is used water suction system. A vacuum within the support screen removes used water from the product, preventing flooding of the product and reduction in the effectiveness of the jets to move the fibers and cause entanglement. Moreover special shape of water suction named, honeycomb help to rectify the water direction [26]. Used water is completely recycled, ***so it is necessary to monitor following parameters:***

Water purity: Water must be free of the air bubbles, calcium salts, bacteria, short fibers and linters and other particles. It is very important, because thin water jet would be clogged up (jet diameter is 80-800 μm) or damaged by any particles dispersed in water.

PH: Neutral to prevent damage of water jet surface.

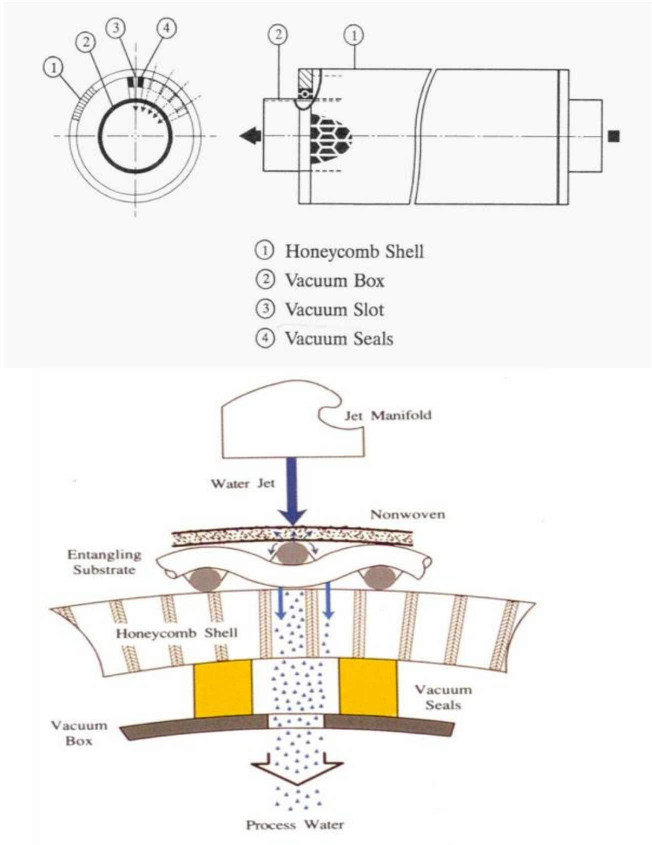

Figure 2.22. Water purification system [26]

Temperature: Warm water decreased bending moment of the fibers and so the bonding efficiency is better. ***Typical water purification system has following stages:***

- ✓ de-ionization unit,
- ✓ heat exchanger,
- ✓ bacteria filter [26]

d. Dewatering, drying

Dewatering, drying usually are used through-air drums seen in Figure 2.23 [26].

Figure 2.23. Dewatering and drying system [26]

CHAPTER 3

MATERIAL AND METHOD

3.1. Introduction

Spunlaced fabrics are noticeable produced for many different used areas having different performance requirements. The physical structures of textile material determine how it will perform, and ultimately whether it is acceptable for a particular use.

Nonwoven tests provide information about the physical and structural properties and the performance properties of the textile. Physical properties include those that characterize the physical structure of the not only nonwoven industry. Physical properties include factors, such as the whiteness. Performance properties are those properties that typically represent the textile response to some type of force, exposure, or treatment. These include properties such as strength, thickness, unit area, tear resistance. Performance properties are always influenced by physical properties. Professionals developing textile products use results from textile testing in selecting materials.

The reasons for carrying out tests on fabrics are numerous and varied, some common ones being [30].

- Fabric conforms to specification,
- Effects of changes in structural details,
- Effects of physical and chemical treatment, exposure to weather, laundering,
- Obtain some indication of probable performance in use,
- Investigate causes of failure and costumer complaints,
- Contribute in design of a fabric for a specific purpose,
- Carry out the interaction of fiber, yarn and fabric properties.

3.2. Materials

In this scope of the study spunlace samples was produced by bonding technology of jetlace system and it was laid as parallel laid. Based on this system spunlace fabric was produced some machine parameters as it was given in Table 3.1. According to these parameters lightweight fabrics from 30 to 120 g/m^2 at very high speeds up to 500 m/min. Production velocity was changed in accordance with fabric weight. For example 220 m/min is used for 40 g/m^2. In this system there are six jets. The pressure of jet is 30-140 bars which is changed according to fabric weight and design. Jetlace is ideal for the production of most synthetic/natural lightweight fabrics for hygiene, medical, and wipes applications. Scaled to meet various line capacity requirements, machines are available in 3.75 m, 4.00 m, 4.25 m, 4.5 m, and 4.75 m widths. Jet diameter is changed 8-15 µm according to type of design and weight.

Table 3.1. Spunlace production parameters

weight (g/m^2)	Production velocity (m/min)	Pressure of jet (b)	Machine width (m)	Jet diameter (µm)	Carding velocity(m/min)
30-120	500	30-140	3.75-4.75	8-15	90

Carding technology

As a major supplier of carding machines, it has developed two ranges of cards according to market needs. Excelle cards are designed for high production levels. Axcess cards are designed for medium production levels.

They are available in 2.50 m, 3.0 m or 3.50 m working width, with different types of delivery configurations parallel, Delivery speeds are adapted to speeds of up to 90 m/min [31].

Figure 3.1 Jetlace system [31]

According to spunlaced manufactured type of nonwovens produced by Mogul Textile Company in Gaziantep, three different weights and five different blend fibers were obtained. Totally fifteen different fibers were examined in Gaziantep University Laboratory and Mogul Textile Company. Samples specifications are given in Table 3.2.

Table 3.2. Sample specifications

Weight (g/m^2)	**Blend Ratio**
30	100% CV
30	30% PES 70% CV
30	50% PES 50% CV
30	70% PES 30% CV
30	100% PES
50	100% CV
50	30% PES 70% CV
50	50% PES 50% CV
50	70% PES 30% CV
50	100% PES
80	100% CV
80	30% PES 70% CV
80	50% PES 50% CV
80	70% PES 30% CV
80	100% PES

Samples were tested by WSP standards which are World Strategic Plan, and as mentioned above material and method section, nonwoven fabrics was examined by their performance properties tested as follows;

- Thickness
- Tensile Strength
- Elongation at Break
- Tear Resistance
- Absorbency Capacity
- Absorbency Time
- Whiteness

In this study it was investigated that effect of weight and blend fiber on performance properties of spunlace fabric. Table 3.3 shows the test name and the number of standards, also Table 3.4 represents the polyester and viscose properties which was used in this thesis.

Table 3.3. Test name and the number of standards.

Test name	**The number of standards**
Thickness	WSP 120.6 (05)
Tensile Strength and Elongation	WSP 110.4 (05)
Tear Resistance	WSP 100.2 (05)
Absorbency Capacity	WSP 10.1 (05)
Absorbency Time	WSP 70.3 (05)
Whiteness	ISO 105-J02:1997

Table 3.4. Polyester and viscose psychical properties is used in this study

Fiber	Linear Density (Dtex)	Cut Length (mm)	Moisture (%)	Tenacity (cN/tex)	Elongation (%)
Polyester (PES)	1.4	38	0.5	55.5	25
Viscose (CV)	1.7	40	10.5	24	14

(a) (b)

Figure 3.2 Cross section of (a) Polyester and (b) Viscose Fiber

3.3. Method

3.3. 1. Standard Test Method for Mass per Unit Area

What is the World Strategic Plan (WSP) test method?

WSP 1.0-04 Standard Terminology Relating to the Nonwoven Industry, EDANA's and INDA's Standard Test Methods in mass unit area is expressed in grams per square meter. It should be determined by cutting test specimens from a larger sample of nonwoven and measuring the area and mass of each test specimen. In the table figured ten samples average which took different nonwoven fabrics.

Mass measurement was done by cutting test specimens the accurate size 50.000 mm^2 usually samples chosen by 250 mm x 200 mm and ten different samples in order to determine the mass of each test specimen, using the precision scales shown in Figure 3.3 to an accuracy of at least 0.1% of the mass, it was calculated the mass per unit area of each test specimen which means value in g/m^2 ten different samples examined and calculated average of them. Ten samples calculated averaged data for each fabric.

Figure 3.3 Cutting test razor and precision scales [32]

3.3.2 Standard Test Method for Nonwoven Thickness

The thickness values of most nonwoven fabrics are considerably depending on the pressure applied to the specimen at the time the thickness measurement is taken. In all cases, the apparent thickness varies inversely with the pressure applied. For this reason it is essential that the pressure be specified when discussing or listing any thickness value. In this study used for thickness device was SDL ATLAS represented in Figure 3.4 examined ten different tested from each samples, and calculated as average thickness value [33].

Measurements carried out under standard atmospheric conditions, the reference plate placed on the speed adjustment button quickly before the presser foot onto the fabric and then slowly lowered, as soon as presser foot pressure reaches the set value, the thickness of the fabric is digitally recorded in mm. Ten samples calculated averaged data for each fabric.

Figure 3.4. SDL Atlas Thicknesses [34]

3.2.3. Test Method for Absorbency Time and Absorbency Capacity

WSP 1.0-04 Standard Terminology Relating to the Nonwoven Industry, EDANA`s and INDA`s Standard Test Methods Standard Test Methods.

3.2.3.1. Absorbency time

Six different test specimens were cut measuring (76 X 165) mm in machine direction and of sufficient length in the cross direction so that they each weigh (5 ± 0.1) g. These strips equally spaced across the fabric sample. The Fluid has to be left long enough to equilibrate with the conditioned atmosphere. Dropped the basket, on its side, from a height of (25±1) mm from the liquid surface into the container of the specified liquid and start the chronometer and saved the time taken for the basket to completely sink below the surface of the fluid [35]. It was calculated the average for six different samples in absorbency time was illustrated in Figure 3.5.

Figure 3.5. Absorbency capacity devices [36]

3.2.3.2. Absorbency capacity

Mass of liquid that is absorbed by unit mass of the test absorbent expressed as a percentage of the mass of the test absorbent under specified conditions and after a specified time [36].

Six different test specimens were cut (100 ± 1) mm x (100 ± 1) mm from the fabric. The Fluid left long enough to equilibrate with the conditioned atmosphere. Weigh the test samples to an accuracy of 0.01 g, using the balance and the weighing glass with cover. Placed the test samples on the stainless steel wire filtering, bonding them at the edges with the clips. Placed the wire filtering with the attached test specimen(s) approximately 20 mm below the fluid surface in the dish and start the chronometer. Introduce the wire filtering from on side in order to avoid trapping air bubbles. After (60 ± 1) s remove the wire filtering test samples support and test specimen, removed all clips but one at one corner. Use fresh conditioned test liquid for each set of test samples, which calculated the absorbency capacity (LAC) in % of each specimen or each pile from the following and the average absorbency capacity of the six test specimens.

$$LAC\% = \frac{M_n - M_k}{M_k} \times 100\% \tag{3.1}$$

Mk: mass in g of the dry test specimen(s)

Mn: mass in g of the wet test specimen(s) at the end of the test.

A hydrophilic fiber

Absorbency time and absorbency capacity are the two most important performance parameters to be considered for absorbency applications. The absorbency capacity is mostly determined by the space between the fibers, and the resiliency of the fabric web in a wetted state. The absorbency rate is determined by the fabric's capillary action offset by the frictional drag of the fiber surfaces. Non-swelling fibers like polyester offer exceptional capillary action and low drag, so these fibers are great for distributing moisture through the fabric. Swelling fibers, like cotton, bamboo and hemp, slightly increase the absorbing capacity and greatly improve the holding capacity when a fabric is under the pressure.

The absorbency time and absorbency capacity are affected by fiber mechanical and surface properties, structure of the fabric (i.e., the size and the orientation of flow channels), the nature of fluids imbibed, and the manner in which the web or the product is tested or used. Among those factors, the surface wetting characteristics (contact angle) of the fibers in the web and the structure of the web, such as the size, shape, orientation of capillaries, and the extent of bonding, is most important.

The type of the fibers in the fabrics, hydrophilic (absorbs and swells: cotton, bamboo, hemp) or hydrophobic (does not absorb or swell: polyester, nylon, influences the inherent absorbency properties of the fabrics. A hydrophilic fiber increases the capacity when it swells, capturing moisture inside the fiber. It also attracts and holds liquid on the outside the fiber, in capillaries, and the structural voids of the fabric. On the other hand, these properties reduce moisture distribution through the fabric and these fibers generally collapse the fabric web, so the ability to hold moisture in the fabric web is greatly diminished once these fabrics are saturated. Hydrophobic fibers do not absorb moisture into their fibers; they do however the effect of the small amount of fiber finish (generally 0.1 to 0.5% by weight) is also important since it is on the fiber surface. The particular finish applied on the fiber can significantly change surface wetting property of the fiber [25]. Thanks to this process polyester was a hydrophilic fiber, and it was gained higher moisture.

3.2.4. Tensile Strength and Elongation at Break

Tensile is the strength of a material when subjected to either pulling or to compressive stress test. It measures the stress a material can bear without breaking or tearing. High precision electronic test instrument that measures the elongation, tensile strength, tear strength or resistance to compression of materials while pulling or compressing forces are applied to the material [37].

Tensile strength examined by contribution to the WSP standard and the brand of Titan Universal test device shown in Figure 3.6 which is connected with computer via its special software. In this test from each laboratory sample test, five samples from the machine direction and six specimens from the cross direction totally twelve different samples cut each specimen 50 ± 0.5mm wide by at least 200 mm, But 300 mm can be cut to fit easily in jaw.

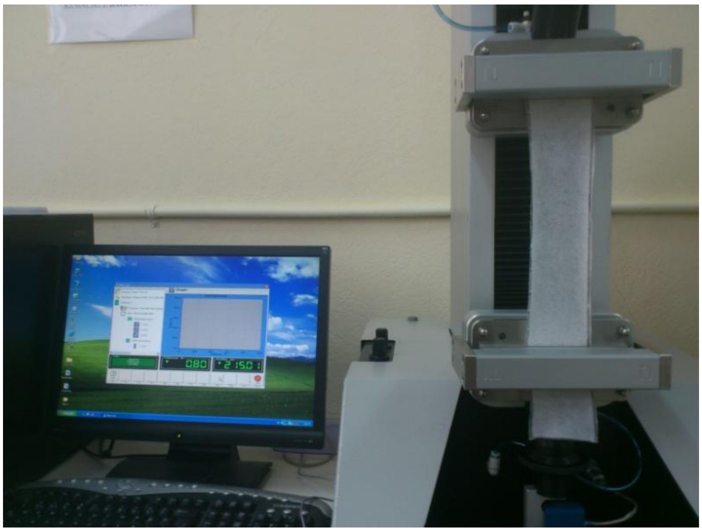

Figure 3.6. Titan Universal Tensile test device

The long dimensions are parallel to the direction for which the breaking force is required. In order to measured samples to moisture equilibrium in the standard atmosphere for testing nonwovens as directed equilibrium is considered to have been reached when the increase in mass of the samples in successive weighing made at intervals of not less than 2 hours does not exceed 0.25 % of the mass of the samples. All samples calculated the average of the breaking force observed for all acceptable samples that is the maximum force applied on the specimen as taking directly from the testing machine.

3.2.5. Test Method for Tearing Resistance of Nonwoven

For nonwovens, the tearing force is recorded as the maximum force required continuing a tear previously started in a fabric. The tearing force may appear as a single peak or a series of peaks on a force-extension curve, depending on the nature of the material. Typically for nonwoven fabrics, if a small decrease in force occurs at a time when the applied force is increasing, it is not considered as a peak unless the indicated force exceeds the force required to break, individually or collectively, the fibers, fiber bonds, or fiber interlocks. Lower shifts corresponding to fiber movement do not qualify as peaks since the fibers, fiber bonds, or fiber interlocks are not broken. The trapezoid tearing force may be calculated from a single-peak or multiple-peak force-extension curve. An outline of is marked on a rectangular specimen cut for the determination of tearing shown Figure 3.7 [38].

All samples tested by Zwick Roell devices are seen in Figure 3.8 and the test from areas of the sample that is free of folds, wrinkles and any distortions that would make these samples unusual from the rest of the test material. samples took as carefully fom not contact any contaminants such as soap, salt, oil etc., which possible facilitate or hinder water penetration.

Zwick is used to evaluate the mechanical and physical properties and performance of materials and components, and have a growing business in the dynamic test segment [39]. Samples cut 75 x 150 mm and marked as shown in Figures 3.7.

Samples cut five specimens in each direction MD and CD, totally samples which chosen mainly significant that the cutting out of the specimen as well as the start of the tear is perfect to avoid any negative influence on the result and that the samples cut perfectly with the direction of the test (MD and CD). At the start of the test the distance between clamps shall be at 25 ± 1mm (1 ± 0.05) All samples calculated the average of the tearing resistance which observed for all acceptable samples that is the maximum force applied on the specimen as taking directly from the testing machine [38].

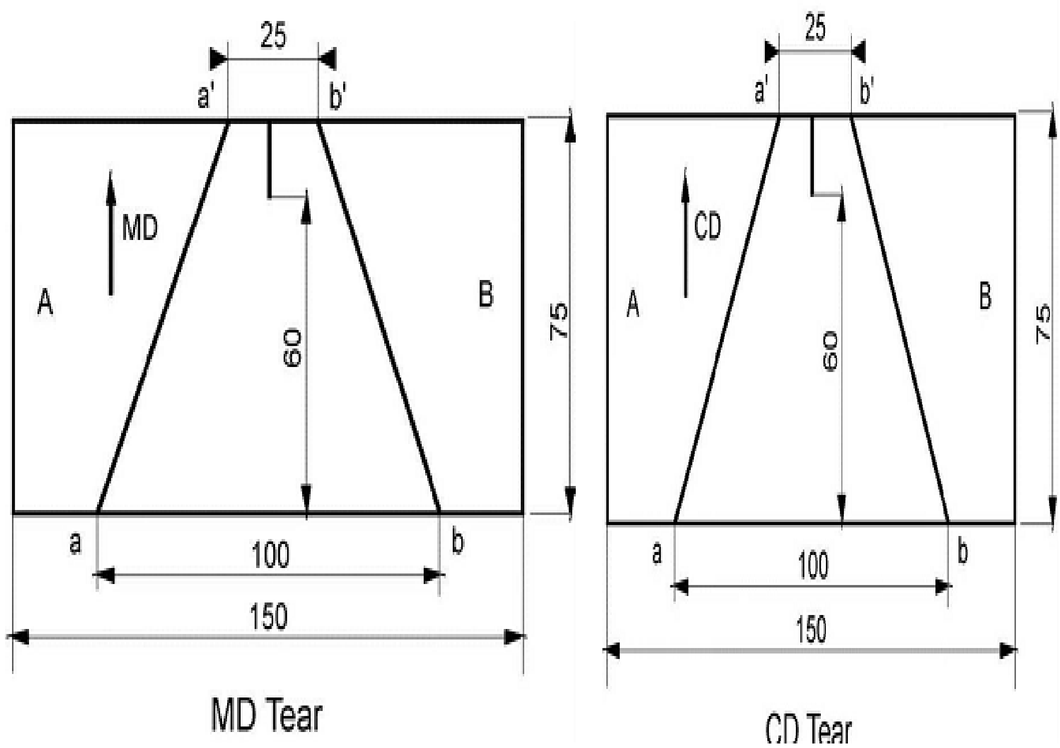

Figure 3.7. Determination of tearing resistance [38]

Figure 3.8. Zwick/Reoll tear resistance

3.2.6. CIE Whiteness

CIE whiteness index: A measure of whiteness derived from measurements of the CIE tristimulus factors under the conditions specified in this method. This method is to be used to determine the CIE whiteness of white or near white specimens with or without optical brighteners. Whiteness differs fundamentally brightness in that whiteness includes the entire visible spectrum in its assessment whereas brightness includes only the blue portion of the spectrum [40].

3.2.6.1. Apparatus

Instrumental components: consisting of a means for fixing the location of the surface of the specimen system for proper illumination of the specimen, suitable filters or monochromatic for altering the spectral character of the rays reflected from the specimen, photosensitive receptors located to receive the rays reflected by the specimen and a means of transforming the receptor signals to tristimulus functions shown in Figure 3.9 [40].

Figure 3.9. Data color 560 CIE whiteness devices

3.2.6.2. Test specimen

From each test unit of the fabric obtained in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product which is fabric," cut the sample to be tested into pieces large enough to extend at least 1/4 inch beyond all edges of the instrument aperture. Assemble the pieces into a pad which is thick enough so that doubling the pad thickness does not change the test readings (With creped or other bulky papers care must be taken to avoid pillowing of the pad into the instrument by too much pressure). Do not touch the test areas of the specimens with the fingers, and protect them from contamination, excessive heat or intense light [41]. White assessment the method proposed by the CIE. The method's components for the 10° observer is: Instrument with illumination resembling daylight

$$\text{Whiteness (CIE)} = Y + 800 * (xn - x) + 1700 * (yn - y) \quad (3.2)$$

Where Y is the Y tristimulus value of the sample, x and y are the x, y chromaticity coordinates of the sample, and xn, yn are the chromaticity coordinates of the perfect diffuser, all for the CIE 1964 supplementary standard colorimetric observer. With the tristimulus values for standard illuminant D65: X = 94.81. Y = 100.00 and Z = 107.33 and the chromaticity co-ordinates x = 0.313795 and y = 0.330972 calculated from them the formula can be re-solved as follows (valid for D65/10°).

$$\text{Whiteness (CIE)} = Y + (-800 * x) + (-1700 * y) + 813.6890 \quad (3.3)$$

The lightness Y is weighted with 1 in formula, and it can be given the same structure as customarily assigned to the whiteness formula (Ganz) with the parameters D, P, Q, C. [42].

$$\text{Whiteness (CIE)} = (D * Y) - (P * x) - (Q * y) + C \quad (3.4)$$

CHAPTER 4

EXPERIMENTAL RESULT AND DISCUSSION

4.1. Introduction

In the following this sections, the results which were obtained from the evaluation of the samples formed by using an experimental study which was given as in Chapter 3. In this chapter, the results obtained from the evaluation of the fabrics the term of weight and blend fiber, and statically analyzes.

First of all, the result of performance properties was given and discussed, secondly two different graphic is prepared about weight effect on performance properties and blend fiber effect performance properties, after that read the data discussed relationship between blend fiber and weight. Thirdly, statistical analyses result was given ANOVA Tables and discussed the significance level of performance properties, at the end of this section correlation analyzes was given examined all performance properties relationship between each other, after regression analyzes is performed and equation was calculated in order to understand the relationship between the weight and fiber and performance properties.

4.2 Purpose and Principal

In this study, performance properties of spunlace nonwoven fabrics which were produced by polyester / viscose blend fibers were investigated. For this purpose, influence of five different blend fibers and three different weights were examined on spunlace fabric.

In this thesis tests was determined as below experiments

- ✓ Thickness,
- ✓ Absorbency capacity and time,
- ✓ Tensile strength and elongation at break,
- ✓ Tear resistance,
- ✓ Whiteness

As well as so as to evaluate the statistical significance of spunlace fabric properties analysis of variance (ANOVA) was performed breaking strength and elongation, absorbency, tear resistance, thickness properties, furthermore these correlation analysis was calculated to demonstrate the correlation between fabric properties from statistical method. Also, regression analysis was used to calculate the relationship between independent variables (weight and blend fiber) and response variables (strength and elongation). For this purpose the statistical software package SPSS 15.0 was chosen to use in order to give information about experimental data. All test results were evaluated significance levels of $\alpha \leq 0.05$ and $\alpha \leq 0.01$. The result of statistical analysis has been given in Appendix A.

4.3. The Test Resulting of Thickness

The test was carried out under standard atmospheric conditions, the reference plate placed on the speed adjustment button quickly before the presser foot onto the fabric and then slowly lowered, as soon as presser foot pressure reaches the set value, the thickness of the fabric is digitally recorded in mm thickness value depends on the fibers [43]. The average of ten samples data for each fabric was calculated also, fiber density and fiber ratio. The result of thickness are shown in Table 4.1

The effect of blend ratio on thickness is seen in Figure 4.1 thickness exchange in five different blend fibers. It was indicated that the thickness value was increased in all weights by increasing the polyester ratio in composition. This can be caused from the fiber density and fiber ratio differences between polyester and viscose. Polyester fiber density is 1.38 g/cm^3 and viscose fiber density is 1.52 g/cm^3 [44], also viscose fiber's pack ability is higher than polyester fibers due to its fiber structure. In same weight viscose has better pack ability than polyester, thus polyester thickness value is higher than viscose. In low weight polyester has much more air than viscose, when there is more amount of air in fibers, they can be packable more. In Figure 4.2 illustrates the effect of weight on thickness value. Based on the result, increasing the unit weight of fabric, it was observed that the thickness increases as direct proportional. This situation reason is the fibers amount increased in the structure, so this makes samples become thicker and increase cross sectional area. Based on the Figure the highest value was obtained with 80 g/m^2 and the lowest was obtained with 30 g/m^2.

Table 4.1. Test result of thickness

Raw material	Weight (g/m^2)	Thickness (mm)	Cross Sectional Area (cm^2)	Fiber Density (g/cm^3)	Fiber Ratio (%)
100% CV	30	0.43	0.215	0.0698	4.56
30% PES-70% CV	30	0.432	0.216	0.0682	4.59
50% PES-50% CV	30	0.436	0.218	0.0672	4.62
70% PES-30% CV	30	0.45	0.225	0.0652	4.64
100% PES	30	0.464	0.232	0.0646	4.68
100% CV	50	0.566	0.283	0.0883	5.81
30% PES-70% CV	50	0.59	0.295	0.085	5.75
50% PES-50% CV	50	0.596	0.298	0.0828	5.71
70% PES-30% CV	50	0.602	0.301	0.0806	5.67
100% PES	50	0.646	0.323	0.0774	5.61
100% CV	80	0.726	0.363	0.1102	7.25
30% PES-70% CV	80	0.73	0.365	0.1061	7.17
50% PES-50% CV	80	0.74	0.37	0.1035	7.13
70% PES-30% CV	80	0.774	0.387	0.1008	7.08
100% PES	80	0.826	0.413	0.0968	7.01

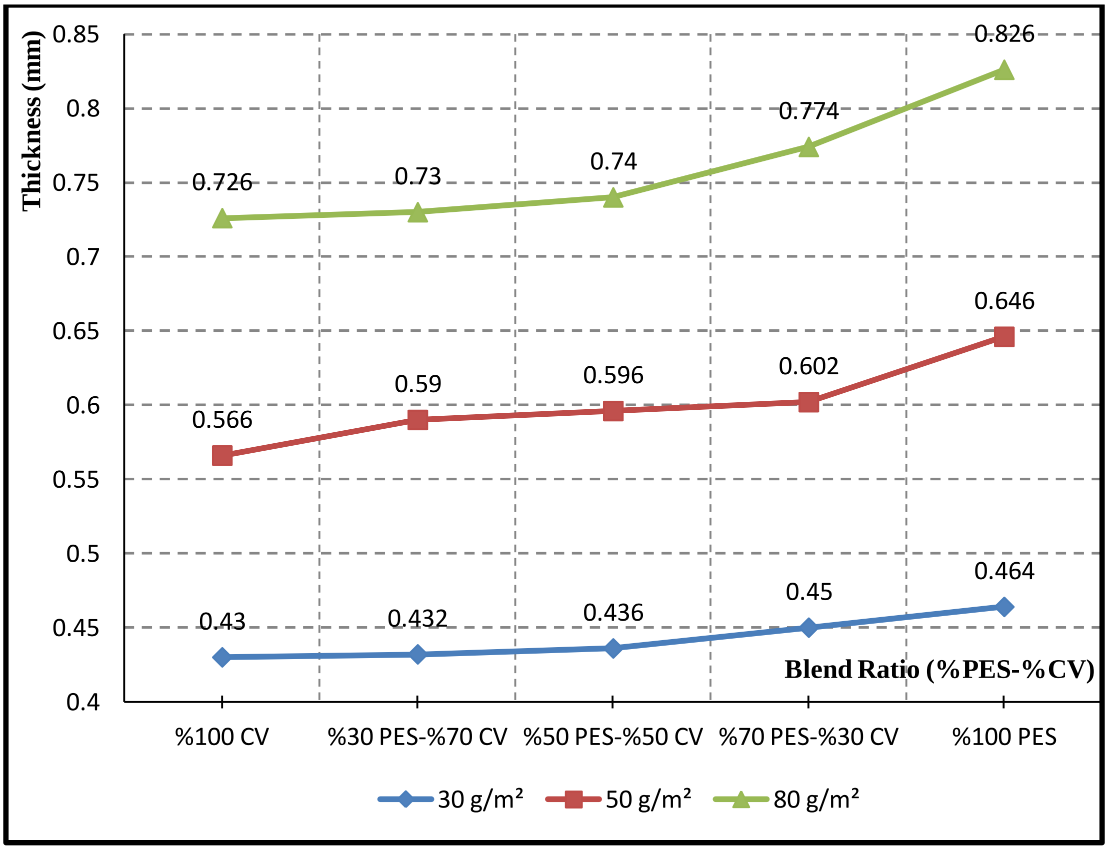

Figure 4.1. Thickness exchanges in different blend fiber for 30-50-80 g/m² weights

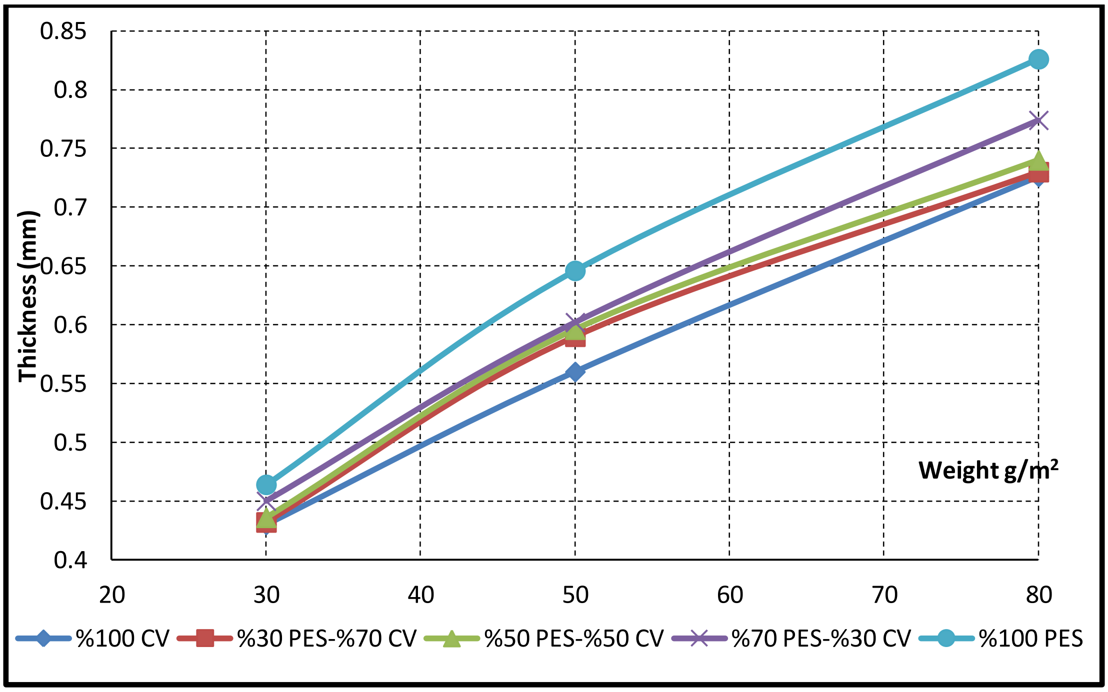

Figure 4.2. Thickness exchanges in different weight for blend ratio (%PES-%CV)

Five different blend fibers were investigated and analyzed as given in Table 4.2. All blend fiber results were found in significant level on the ANOVA table. If this value were over than 0.05 the interpretation could have been evaluated as meaningless. To examine statistical effect of weight on thickness ANOVA tests were performed. The results can be seen that the effect of spunlace fabric weight (30-50-80 g/m^2) on thickness is significant ($p \leq 0.01$) at 1% significance level (see in Table 4.3). Three different weights were investigated separately to obtain proper result.

Table 4.2. ANOVA Table blend fiber effect on thickness

		Sum of Squares	Df	Mean Square	F	Sig.
v100	Between Groups	0.439	2	0.220	1384.822	0.000
	Within Groups	0.004	27	0.000		
	Total	0.443	29			
v70	Between Groups	0.442	2	0.221	1834.532	0.000
	Within Groups	0.003	27	0.000		
	Total	0.445	29			
v50	Between Groups	0.463	2	0.231	1139.387	0.000
	Within Groups	0.005	27	0.000		
	Total	0.468	29			
v30	Between Groups	0.526	2	0.263	1773.720	0.000
	Within Groups	0.004	27	0.000		
	Total	0.530	29			
v0	Between Groups	0.655	2	0.328	4607.063	0.000
	Within Groups	0.002	27	0.000		
	Total	0.657	29			

Table 4.3. ANOVA Table effect of weights on thickness

		Sum of Squares	Df	Mean Square	F	Sig.
W30	Between Groups	0.008	4	0.002	7.248	0.000
	Within Groups	0.013	45	0.000		
	Total	0.021	49			
W50	Between Groups	0.034	4	0.008	116.341	0.000
	Within Groups	0.003	45	0.000		
	Total	0.037	49			
W80	Between Groups	0.071	4	0.018	282.811	0.000
	Within Groups	0.003	45	0.000		
	Total	0.073	49			

4.4. Test resulting of Tensile Strength in CD and MD

Six samples were investigated by tensile strength in cross direction (CD) and machine direction (MD) represents in Table 4.4. Tensile strength exchange in different blend fiber for different weight Figure 4.3 and 4.5 were shown respectively. It was illustrated that increasing the polyester ratio in MD and CD, the performance value was increased with direct proportion. Polyester was stronger than viscose fiber seen in Table 3.3 [46]. Thus, greater polyester ratio provides more strength to the nonwoven fabric sample. The highest tensile strength was obtained with 100% Polyester and the lowest was obtained with 100% Viscose in both MD and CD. Tensile strength in CD and MD sharply raise from 70% PES- 30% CV blend to 100% PES in 50 g/m² and 80 g/m² weights. Tensile strength in CD and MD sharply raise from 70% PES- 30% CV blend to 100% PES in 50 g/m² and 80 g/m² weights. As it is illustrated Figure tensile strength in CD and MD sharply raise from 70% PES- 30% CV blend to 100% PES in 30 g/m², 50 g/m² and 80 g/m² weights. The highest tensile strength was obtained with 100% Polyester and the lowest was obtained with 100% Viscose in both MD and CD. Also Figure 4.4 and 4.6 exhibit effect of weight on tensile strength in CD and MD, it was demonstrated that the tensile strength value increased with increasing unit weight in all ratio. This situation can be explained when the weight was increased in MD and CD, the number of fibers in per unit area increased with direct proportion, and this caused the tensile force was enhanced. The highest tensile was obtained in 80 g/m^2 and lowest was obtained in 30 g/m^2. As Figure 4.4 and 4.6 illustrated that tensile strength value in MD is higher than CD, because spunlace fabric is laid as parallel laid there is much more fiber than in CD due to winding up process is occurred in MD [45].

Table 4.4. Test results of tensile strength

Raw meterial	Weight (g/m²)	T. STRENGTH (N/5cm)		CV(%)	
		MD	CD	MD	CD
100% CV	30	38.33	9.66	4.80	5.27
30% PES-70% CV	30	43.66	10.66	3.77	5.12
50% PES-50% CV	30	45.33	12	2.37	4.72
70% PES-30% CV	30	46	12.66	2.39	4.18
100% PES	30	66	13.66	1.90	3.77
100% CV	50	85.66	21	1.96	4.50
30% PES-70% CV	50	91	21.33	1.89	4.41
50% PES-50% CV	50	94.33	22.66	2.11	3.94
70% PES-30% CV	50	96.66	25	2.42	4.01
100% PES	50	153	39	1.96	1.62
100% CV	80	122	31.33	2.02	2.60
30% PES-70% CV	80	156.66	32.33	1.78	3.74
50% PES-50% CV	80	157	34.66	1.45	1.47
70% PES-30% CV	80	173.66	38.333	1.61	1.42
100% PES	80	253.33	64	1.31	1.71

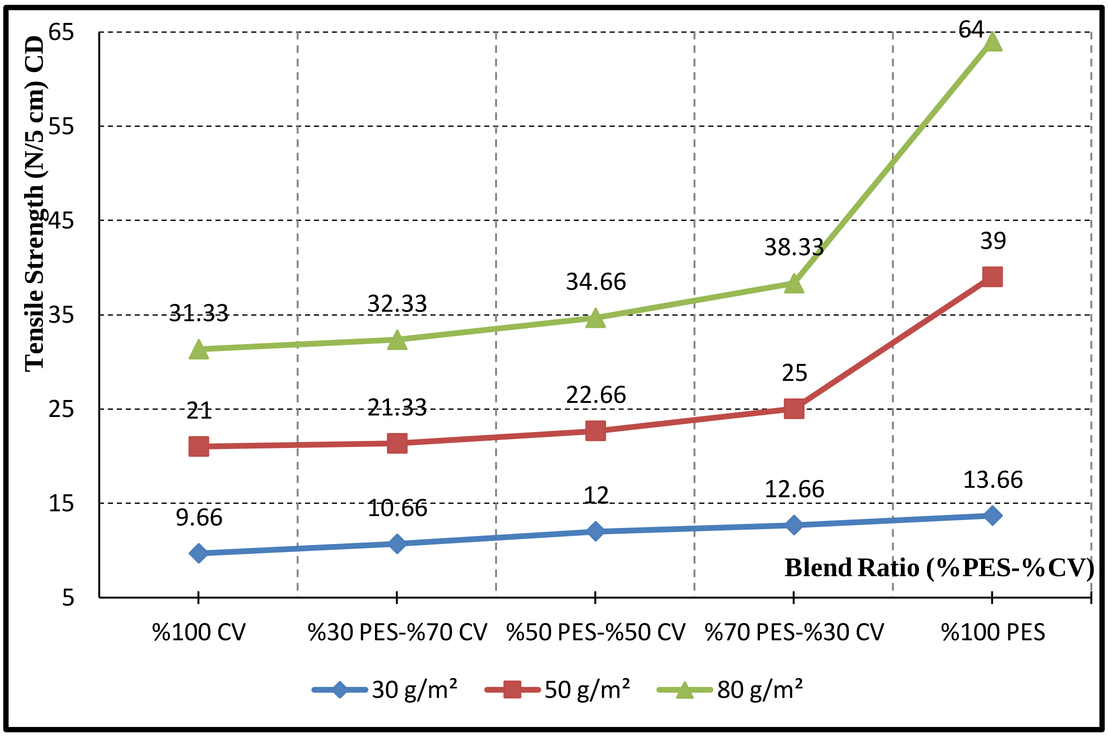

Figure 4.3. T. Strength exchanges in different blend fiber for 30-50-80 g/m² in CD

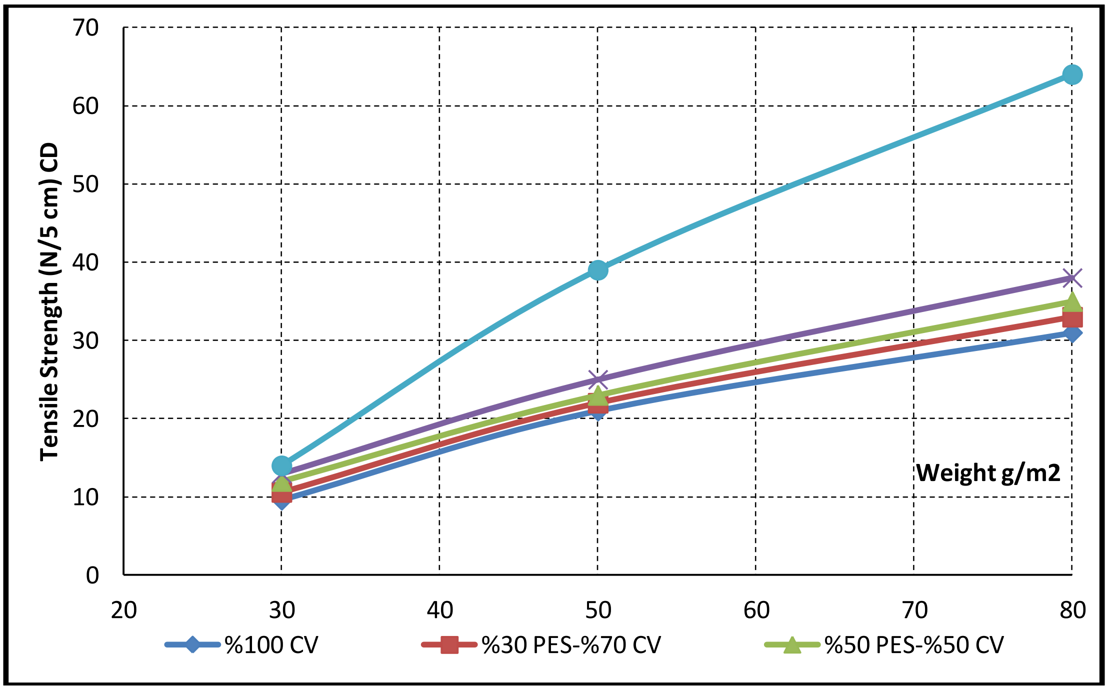

Figure 4.4. Tensile strength exchanges in different weight for blend ratio in CD

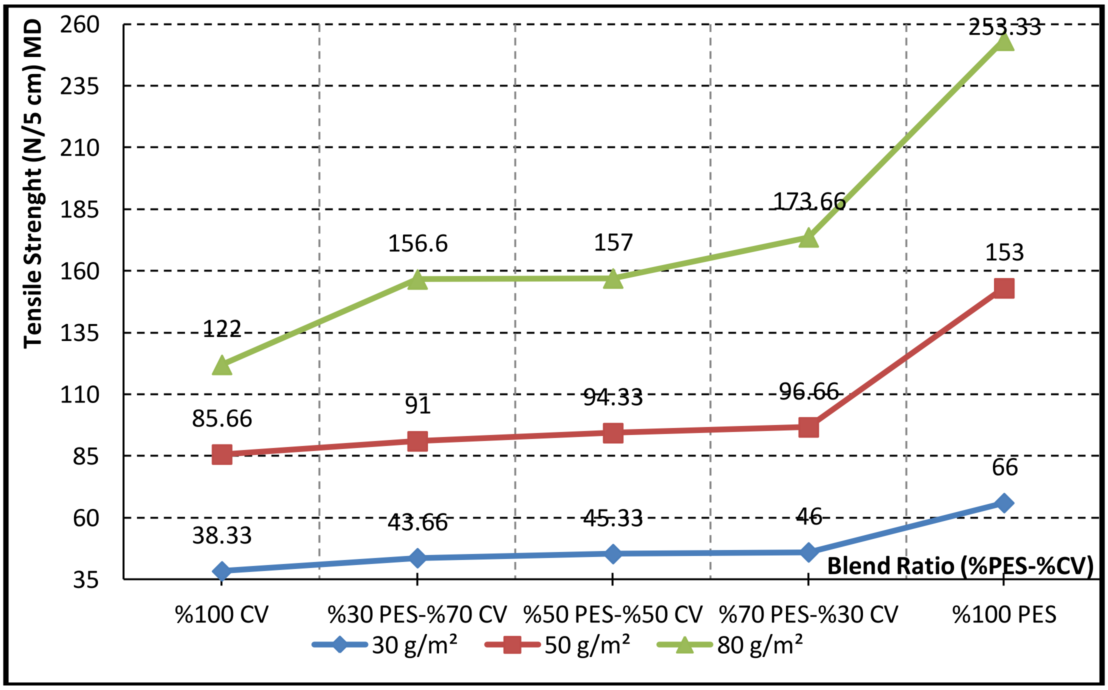

Figure 4.5. T. Strength exchanges in different blend fiber for 30-50-80 g/m ² in MD

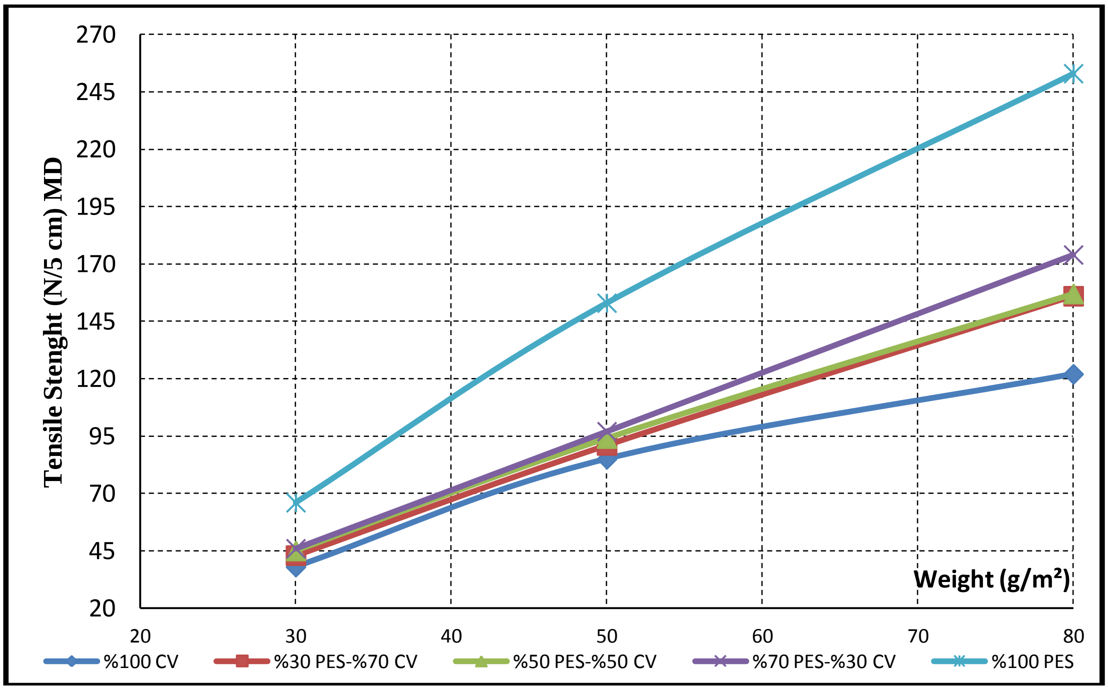

Figure 4.6. T. Strength exchange in different weight for blend ratio in MD

The effect of blend fiber on tensile strength in MD value was found to be significant ($P \leq 0.01$) 1% significance level based on the ANOVA table. (Table 4.5)

Table 4.5. ANOVA Table blend fiber effect on tensile strength in MD

		Sum of Squares	df	Mean Square	F	Sig.
v100	Between Groups	21093.778	2	10546.889	3342.324	0.000
	Within Groups	47.333	15	3.156		
	Total	21141.111	17			
v70	Between Groups	37533.778	2	18766.889	12064.429	0.000
	Within Groups	23.333	15	1.556		
	Total	37557.111	17			
v50	Between Groups	37595.111	2	18797.556	26434.062	0.000
	Within Groups	10.667	15	0.711		
	Total	37605.778	17			
v30	Between Groups	49589.778	2	24794.889	34867.812	0.000
	Within Groups	10.667	15	0.711		
	Total	49600.444	17			
v0	Between Groups	105459.111	2	52729.556	69789.118	0.000
	Within Groups	11.333	15	0.756		
	Total	105470.444	17			

The effect of weight on tensile strength in MD was obtained to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.6)

Table 4.6. ANOVA Table effect of weights on tensile strength in MD

		Sum of Squares	df	Mean Square	F	Sig.
W30	Between Groups	2637.867	4	659.467	549.556	0.000
	Within Groups	30.000	25	1.200		
	Total	2667.867	29			
W50	Between Groups	18469.333	4	4617.333	4026.744	0.000
	Within Groups	28.667	25	1.147		
	Total	18498.000	29			
W80	Between Groups	57588.533	4	14397.133	8058.097	0.000
	Total	57633.200	29			

The effect of blend fiber on tensile strength in CD was determined significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.7)

Table 4.7. ANOVA Table blend fiber effect on tensile strength in CD

		Sum of Squares	df	Mean Square	F	Sig.
v100	Between Groups	1409.333	2	704.667	2265.000	0.000
	Within Groups	4.667	15	0.311		
	Total	1414.000	17			
v70	Between Groups	1408.444	2	704.222	1056.333	0.000
	Within Groups	10.000	15	0.667		
	Total	1418.444	17			
v50	Between Groups	1543.111	2	771.556	1736.000	0.000
	Within Groups	6.667	15	0.444		
	Total	1549.778	17			
v30	Between Groups	2054.778	2	1027.389	1744.623	0.000
	Within Groups	8.833	15	0.589		
	Total	2063.611	17			
v0	Between Groups	7600.444	2	3800.222	6107.500	0.000
	Within Groups	9.333	15	0.622		
	Total	7609.778	17			

The effect of blend fiber on tensile strength in CD was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.8)

Table 4.8. ANOVA Table effect of weights on tensile strength in CD

		Sum of Squares	df	Mean Square	F	Sig.
W30	Between Groups	57.333	4	14.333	38.393	0.000
	Total	66.667	29			
W50	Between Groups	1366.133	4	341.533	800.469	0.000
	Within Groups	10.667	25	0.427		
	Total	1376.800	29			
W80	Between Groups	4442.667	4	1110.667	1423.932	0.000
	Within Groups	19.500	25	0.780		
	Total	4462.167	29			

4.5. The Testing Result of Elongation at Break in CD and MD

The test results of elongation at break of samples was given in Table 4.9.

Table 4.9. The testing result of elongation at break

Raw material	Weight (g/m²)	Elongation At Break (%)		CV(%)	
		MD	CD	MD	CD
100% CV	30	30	140	3.65	1.1
30% PES-70% CV	30	33	145	4.43	2.58
50% PES-50% CV	30	40	150	2.73	2
70% PES-30% CV	30	45	155	2.43	1.22
100% PES	30	50	165	2.19	2.42
100% CV	50	32	145	1.97	1.95
30% PES-70% CV	50	35	150	3.12	1.37
50% PES-50% CV	50	42	156	2.6	3.34
70% PES-30% CV	50	47	160	2.33	1.81
100% PES	50	51	170	2.14	1.94
100% CV	80	35	153	3.12	1.37
30% PES-70% CV	80	40	158	2.73	1.05
50% PES-50% CV	80	45	160	2.43	2.68
70% PES-30% CV	80	50	165	2.19	2.06
100% PES	80	55	175	1.99	2.39

Test results for elongation in cross direction (CD) and machine direction (MD) represents in Table 4.9. Effect of blend ratio on elongation at break in MD and CD was given in Figure 4.7 and 4.9 respectively. According to Figure when the polyester ratio in MD and CD is increased, the elongation values increase. It can be notified that fabric made from polyester fiber has got more bulky structure than viscose due to its own characteristic properties as showed in Table 3.3. The highest elongation value was obtained with 100% polyester, and the lowest elongation was obtained with 100% viscose. Figure 4.8 and 4.10 illustrates the elongation at break exchange in different weight in MD and CD. It was illustrate that, increasing weight in MD and CD, elongation was increased. The highest elongation at break was obtained 80 g/m^2 polyester and the lowest was obtained 30 g/m^2. As, it was noticed that the elongation at break CD value was higher than MD value. This situation was caused from being tensile strength in MD is higher, so it made lower elongation at break value in MD due to indirect proportional was observed between tensile and elongation.

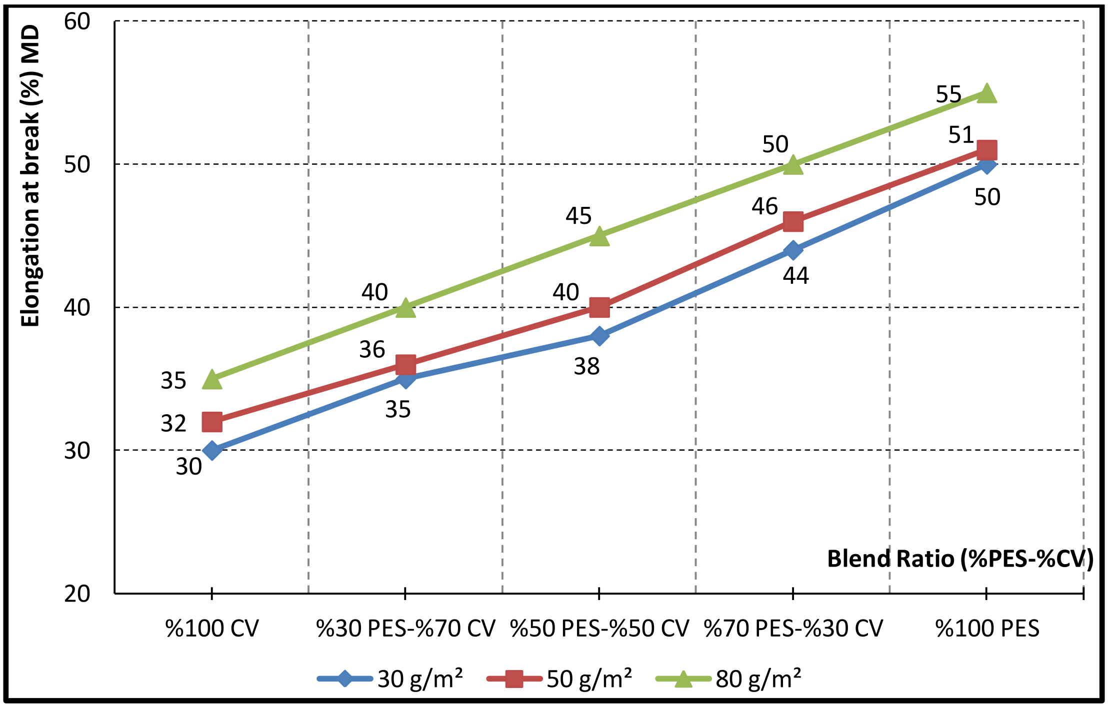

Figure 4.7. El. at break exchange in different blend fiber for 30-50-80 g/m ² in MD

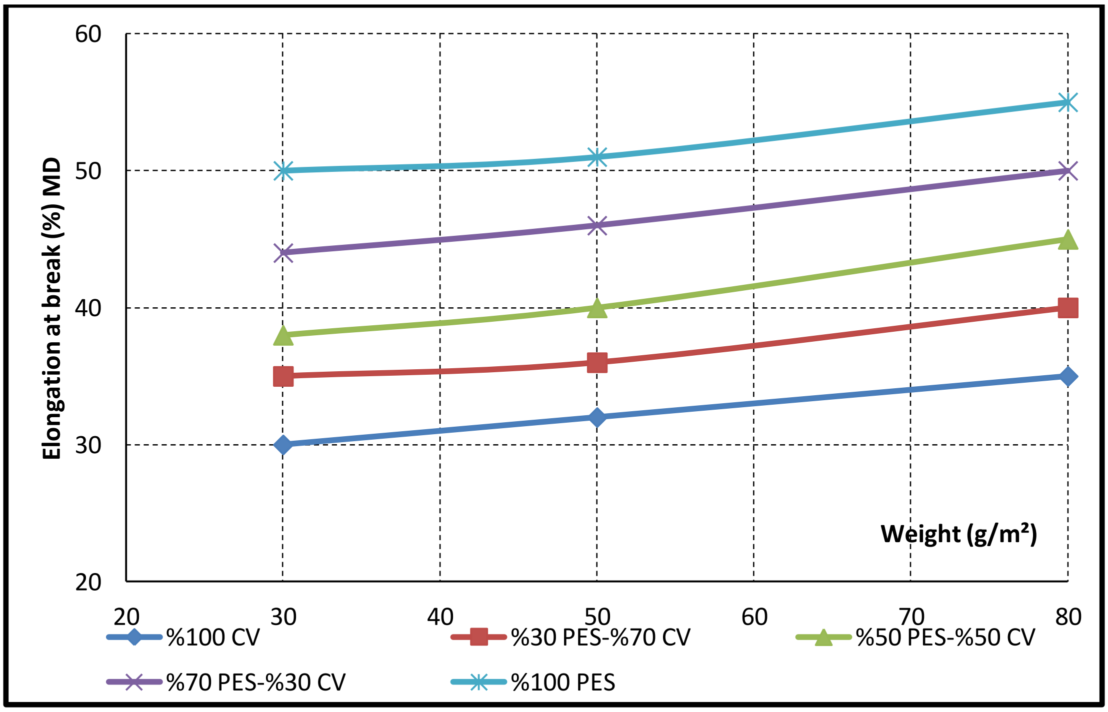

Figure 4.8. Elongation at break exchange in different weight for blend ratio in MD

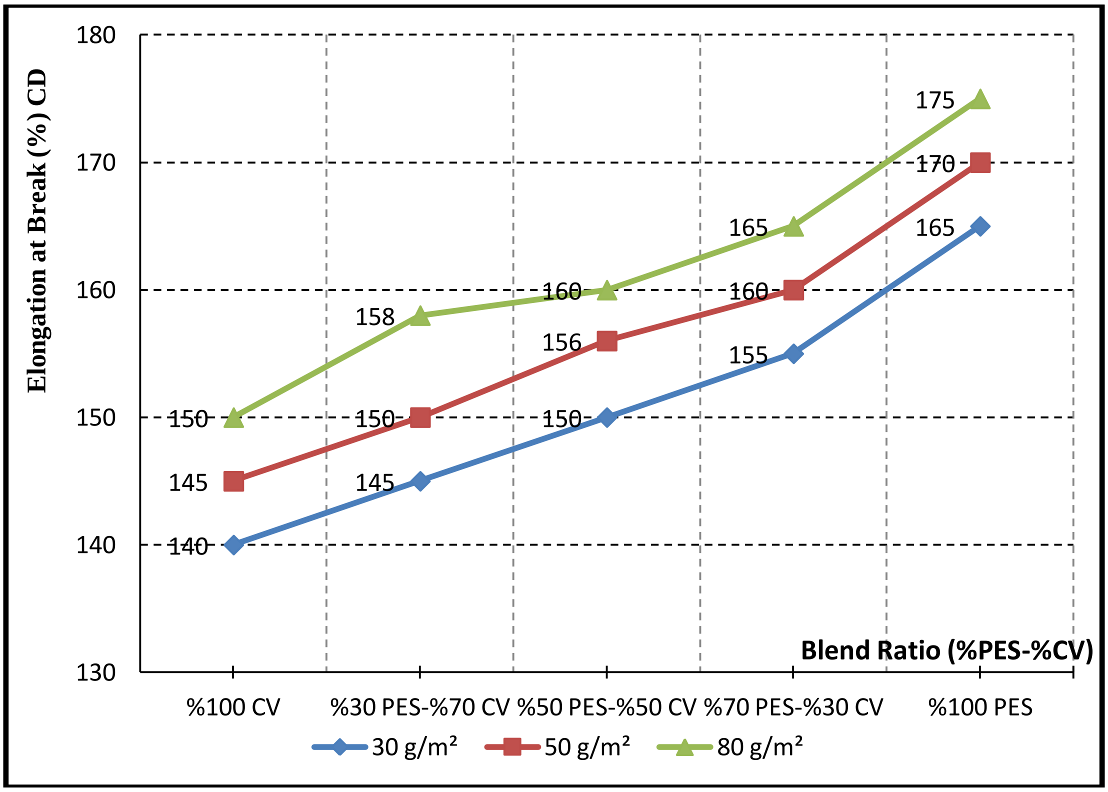

Figure 4.9. Elongation at break exchange in different weight for blend ratio in CD

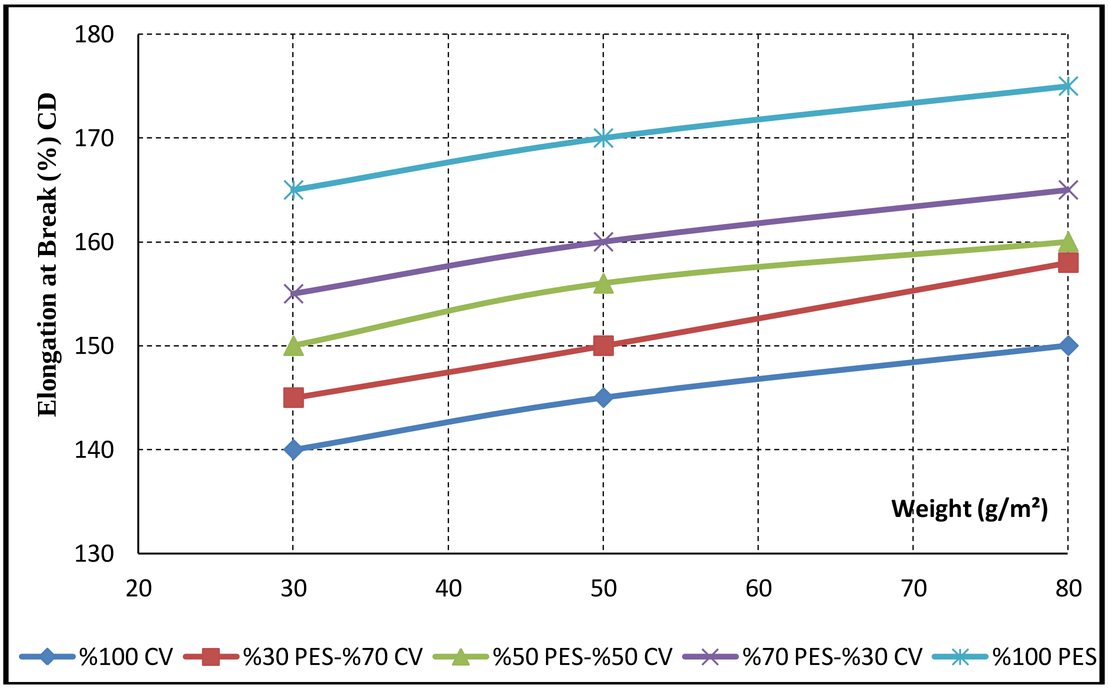

Figure 4.10. Elon. at break exchange in different blend fiber for 30-50-80 g/m² in CD

The effect of blend fiber on elongation at break in MD value was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.10)

Table 4.10. ANOVA Table effect of blend fiber on elongation at break in MD

		Sum of Squ	df	Mean Square	F	Sig.
v100	Between Groups	76.000	2	38.000	40.714	0.000
	Within Groups	14.000	15	0.933		
	Total	90.000	17			
v70	Between Groups	150.111	2	75.056	49.307	0.000
	Within Groups	22.833	15	1.522		
	Total	172.944	17			
v50	Between Groups	76.000	2	38.000	31.667	0.000
	Within Groups	18.000	15	1.200		
	Total	94.000	17			
v30	Between Groups	76.000	2	38.000	31.667	0.000
	Within Groups	18.000	15	1.200		
	Total	94.000	17			
v0	Between Groups	84.000	2	42.000	35.000	0.000
	Within Groups	18.000	15	1.200		
	Total	102.000	17			

The effect of weight on elongation at break in MD value on three different was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.11)

Table 4.11. ANOVA Table effect of weight elongation at break in MD

		Sum of Squ	df	Mean Square	F	Sig.
W30	Between Groups	1626.133	4	406.533	291.770	0.000
	Within Groups	34.833	25	1.393		
	Total	1660.967	29			
W50	Between Groups	1519.200	4	379.800	365.192	0.000
	Within Groups	26.000	25	1.040		
	Total	1545.200	29			
W80	Between Groups	1500.000	4	375.000	312.500	0.000
	Total	1530.000	29			

The effect of blend fiber on elongation at break in CD was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.12)

Table 4.12. ANOVA Table effect of blend fiber on elongation at break in CD

		Sum of Squ	df	Mean Square	F	Sig.
v100	Between Groups	516.000	2	258.000	92.143	0.000
	Within Groups	42.000	15	2.800		
v70	Between Groups	512.444	2	256.222	77.905	0.000
	Within Groups	49.333	15	3.289		
v50	Between Groups	281.333	2	140.667	32.629	0.000
	Within Groups	64.667	15	4.311		
v30	Between Groups	300.000	2	150.000	66.176	0.000
	Within Groups	34.000	15	2.267		
v0	Between Groups	300.000	2	150.000	102.273	0.000
	Within Groups	22.000	15	1.467		

The effect of blend fiber on elongation at break in CD value was found to be significant (P ≤ 0.01) at 1% significance level based on the ANOVA table. (Table 4.13)

Table 4.13. ANOVA table effect of weight on elongation at break in CD

		Sum of Squares	df	Mean Square	F	Sig.
W30	Between Groups	2216.533	4	554.133	188.909	0.000
W50	Between Groups	2190.133	4	547.533	174.004	0.000
	Within Groups	78.667	25	3.147		
W80	Between Groups	1672.800	4	418.200	174.250	0.000

4.6. The Result of Tear Resistance

The test results of elongation at break of samples was given in Table 4.14

Table 4.14. The Result of Tear Resistance

Raw material	Weight (g/m²)	Tear Resistance (N)		CV(%)	
		MD	CD	MD	CD
100% CV	30	16	8	3.95	7.9
30% PES-70% CV	30	22	9.23	2.87	8.74
50% PES-50% CV	30	24	10.46	2.63	9.98
70% PES-30% CV	30	31.33	10.66	2.04	9.99
100% PES	30	36.66	11.33	2.22	4.84
100% CV	50	38.66	9.66	2.11	6.94
30% PES-70% CV	50	41	12.33	4.08	6.36
50% PES-50% CV	50	44.66	15.33	2.31	5.32
70% PES-30% CV	50	51	16.33	2.14	4.99
100% PES	50	75	17.33	1.95	4.71
100% CV	80	45	15	3.44	4.21
30% PES-70% CV	80	78.66	22	3.37	2.87
50% PES-50% CV	80	81.66	26	3.25	3.21
70% PES-30% CV	80	126.33	31.33	2.77	2.57
100% PES	80	175	44.66	2.34	1.15

Figure 4.11 and 4.13 show effect of blend fiber on tear resistance CD and MD. It is indicated that the tear resistance was increased by increasing the polyester ratio in all weight in MD and CD. This situation can be explained by being polyester more flexible than viscose fiber [44]. According to Figure 4.11 and 4.13, the highest tear resistance value was obtained with 100% polyester, and the lowest was obtained with 100% viscose in both MD and CD. Figure 4.12 and 4.14 show effect of weight on tear resistance in CD and MD. It can be said that the tear resistance value is increased, by increasing unit weight amount. This situation can be explained when the unit area was increased in MD and CD, the number of fibers in per unit increased with direct proportion, and this provided the tear resistance was increased as in tensile strength.

According to figures from 30 g/m^2 to 50 g/m^2 the valued of tear resistance increases slightly, on the other hand from 50 g/m^2 to 80 g/m^2 the tear resistance value increased dramatically in MD and CD, this situation can be explained spunlace fabric showed little variation behavior in low weights but, it is showed high variation behavior in high weight. Also the highest value of tear resistance was obtained with 80 g/m^2 and the lowest one was obtained with 30 g/m^2 in MD and CD.

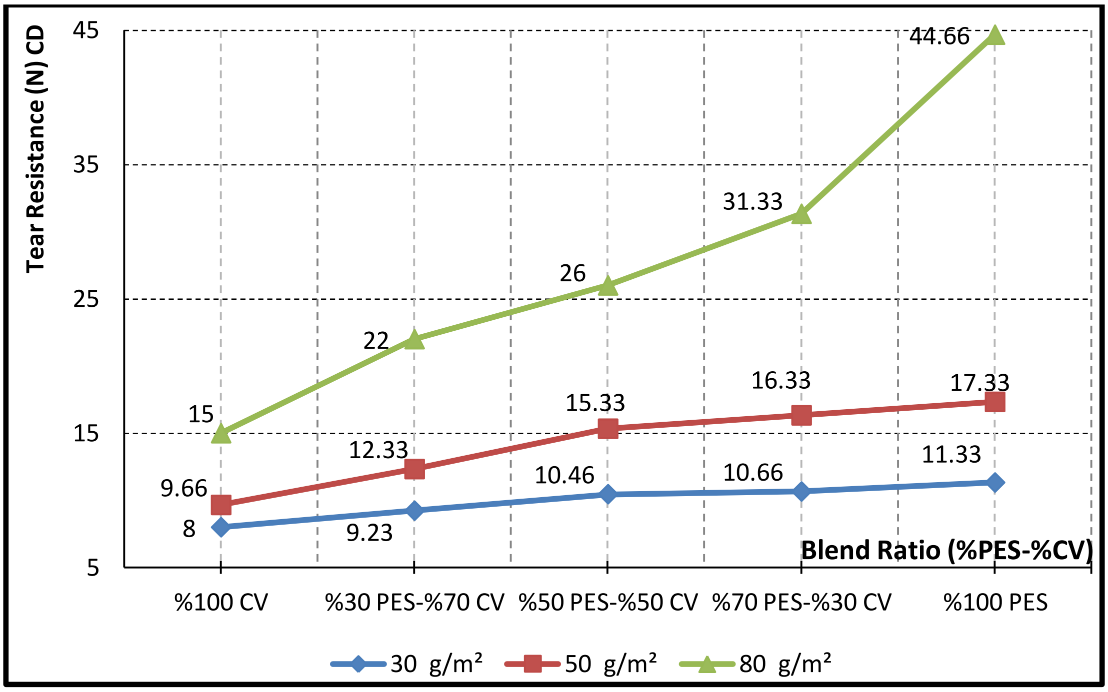

Figure 4.11. T. Resistance exchange in different blend fiber for 30-50-80 g/m^2 in CD

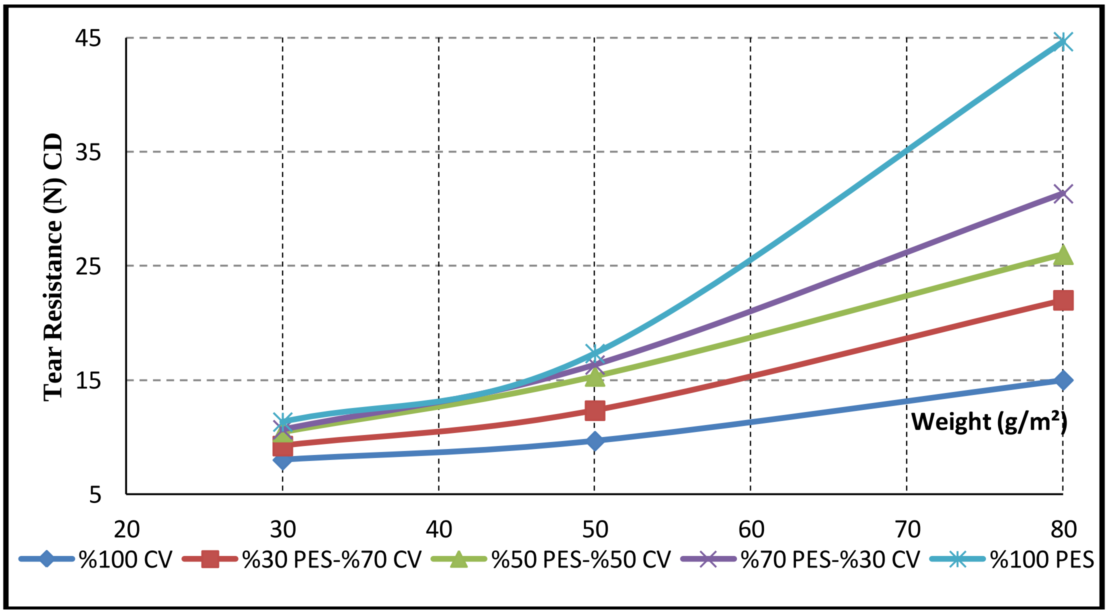

Figure 4.12. Tear resistance exchange in different weight for blend ratio in CD

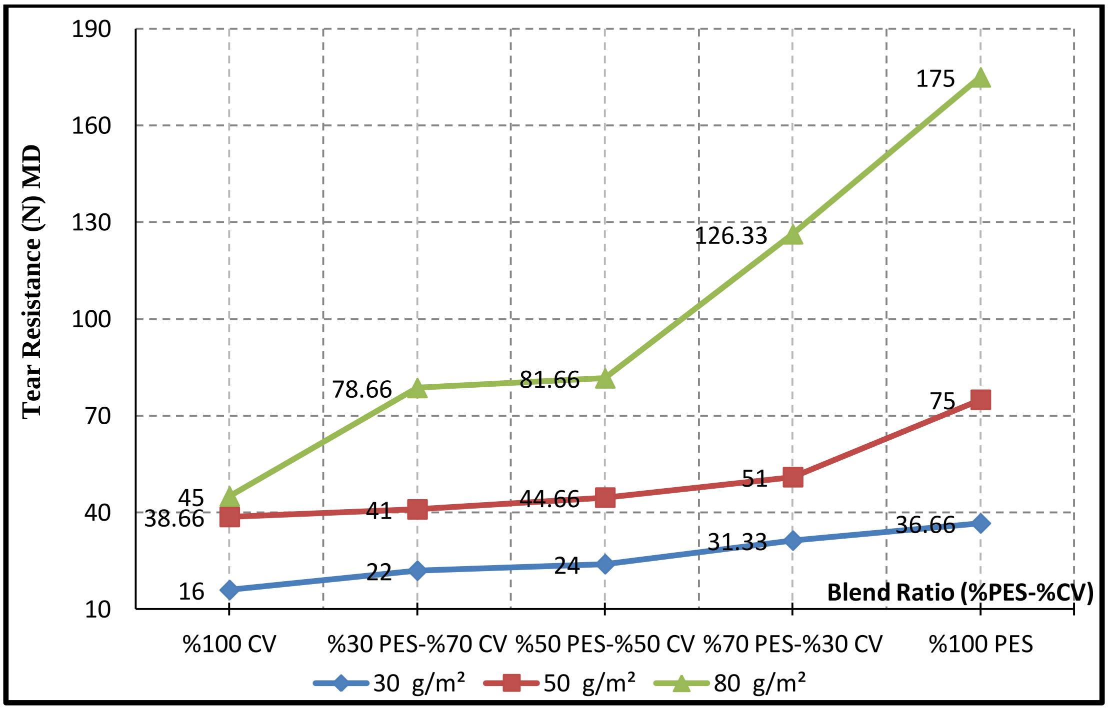

Figure 4.13. T. Resistance exchange in different blend fiber for 30-50-80 g/m² in MD

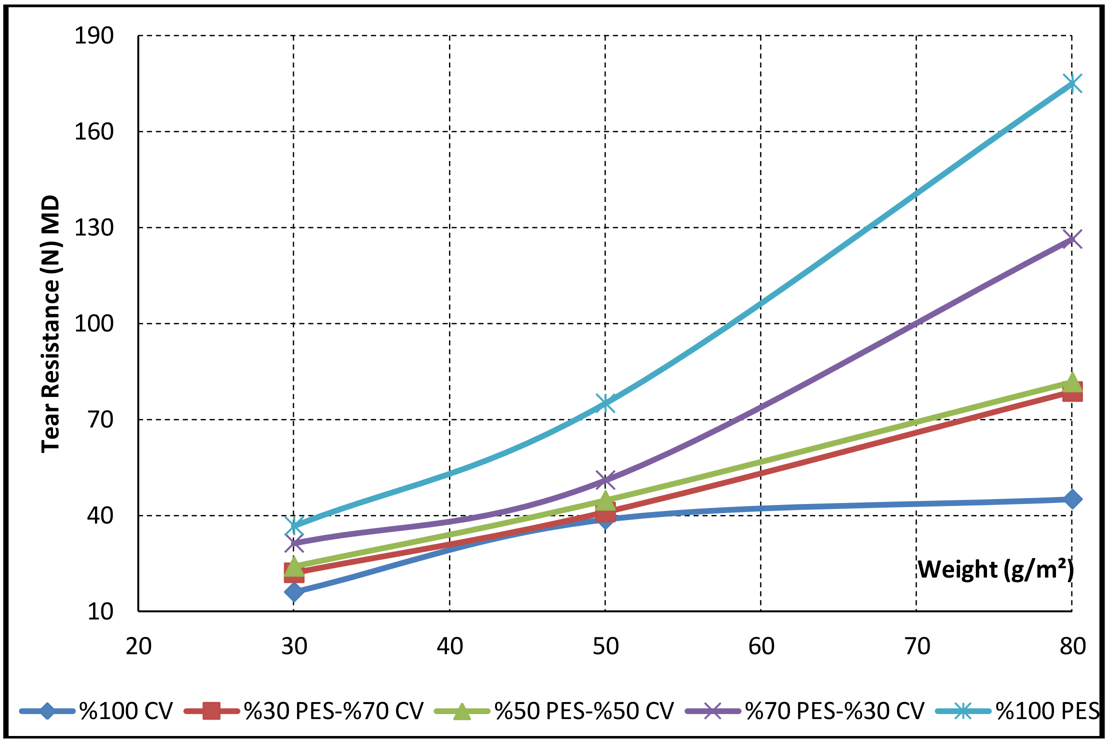

Figure 4.14. Tear resistance exchange in different weight for blend ratio in MD

The effect of blend fiber on tear resistance in CD value was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.15)

Table 4.15. ANOVA Table effects of blend fiber on tear resistance in CD

		Sum of Squares	df	Mean Square	F	Sig.
v100	Between Groups	160.444	2	80.222	90.250	0.000
	Total	173.778	17			
v70	Between Groups	525.778	2	262.889	268.864	0.000
	Within Groups	14.667	15	0.978		
	Total	540.444	17			
v50	Between Groups	761.583	2	380.792	367.520	0.000
	Within Groups	15.542	15	1.036		
	Total	777.125	17			
v30	Between Groups	1368.444	2	684.222	1026.333	0.000
	Within Groups	10.000	15	0.667		
	Total	1378.444	17			
v0	Between Groups	3788.444	2	1894.222	2841.333	0.000
	Within Groups	10.000	15	0.667		
	Total	3798.444	17			

The effect of weight on tear resistance in CD value was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.16)

Table 4.16. ANOVA Table effect of weight on tear resistance in CD

		Sum of Squares	Df	Mean Square	F	Sig.
W30	Between Groups	40.967	4	10.242	10.577	0.000
	Within Groups	24.208	25	0.968		
	Total	65.175	29			
W50	Between Groups	238.133	4	59.533	55.813	0.000
	Within Groups	26.667	25	1.067		
	Total	264.800	29			
W80	Between Groups	2986.133	4	746.533	1473.421	0.000
	Within Groups	12.667	25	0.507		
	Total	2998.800	29			

The effect on blend fiber on tear resistance in MD was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.17)

Table 4.17. ANOVA Table blend fiber effect on tear resistance in MD

		Sum of Squares	df	Mean Square	F	Sig.
v100	Between Groups	2789.778	2	1394.889	2241.786	0.000
	Total	2799.111	17			
v70	Between Groups	9981.778	2	4990.889	8021.071	0.000
	Within Groups	9.333	15	0.622		
	Total	9991.111	17			
v50	Between Groups	10243.111	2	5121.556	7202.188	0.000
	Total	10253.778	17			
v30	Between Groups	30327.111	2	15163.556	17059.000	0.000
	Total	30340.444	17			
v0	Between Groups	61211.111	2	30605.556	40507.353	0.000
	Total	61222.444	17			

The effect of weight on tear resistance in MD value was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.18)

Table 4.18. ANOVA Table effect of weight on tear resistance in MD

		Sum of Squares	df	Mean Square	F	Sig.
W30	Between Groups	1552.533	4	388.133	856.176	0.000
	Within Groups	11.333	25	0.453		
W50	Between Groups	5183.200	4	1295.800	1429.191	0.000
	Within Groups	22.667	25	0.907		
W80	Between Groups	60754.667	4	15188.667	18985.833	0.000
	Within Groups	20.000	25	0.800		

4.7. The Result of Absorbency capacity and time

The test results of absorbency and time was given in Table 4.19.

Table 4.19. Result of absorbency capacity and time.

Raw material	Weight (g/m²)	A. Cap (%)	A.Time (sec)
100% CV	30	1190.33	4
30% PES-70% CV	30	1180	5.86
50% PES-50% CV	30	1175	6.13
70% PES-30% CV	30	1165	6.24
100% PES	30	780	9.8
100% CV	50	1195	4.03
30% PES-70% CV	50	1183	5.9
50% PES-50% CV	50	1777	6.2
70% PES-30% CV	50	1167	6.25
100% PES	50	875	10.16
100% CV	80	1196	4.06
30% PES-70% CV	80	1185	5.95
50% PES-50% CV	80	1178	6.23
70% PES-30% CV	80	1169	6.3
100% PES	80	900	10.26

Figure 4.15 exhibits effect of blend fiber on absorbency capacity. It was indicated that absorbency capacity was increased with viscose ratio. This situation was caused from being viscose fiber was more absorbent than polyester. It can be seen in Table 3.3. As it is seen at the Figure 4.15, all value was so close to each other except for 100% polyester, as known that polyester was not hydrophilic fiber. It can be deduced that capacity of absorbency increased when hydrophilic properties was increased. The highest absorbency value was obtained with 100% viscose, and the lowest is absorbency capacity value was obtained with 100% polyester. In Figure 4.16 shows effect of weight on absorbency capacity. According to Figure when the weight was increased, the absorbency capacity increased slightly, it can be said that there was no

big difference on absorbency capacity except 100 % polyester. This situation can be explained by hydrophilic properties of polyester, as mentioned the absorbency test method polyester fiber was applied on hydrophilic process. Even if polyester was not hydrophobic fiber, it was gained behavior like viscose fiber in this study. The highest value of absorbency was obtained with 80 g/m ^{2} and the lowest was obtained with 30 g/m^2.

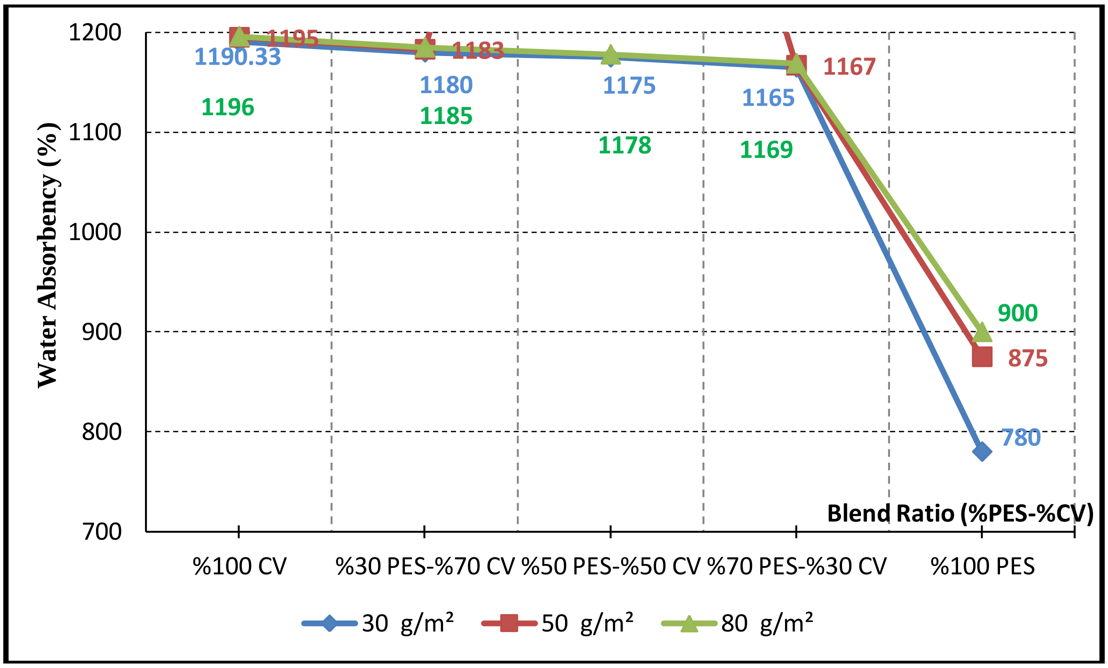

Figure 4.15. Absorbency capacity exchanges in different blend fiber for 30-50-80 g/m ^{2}

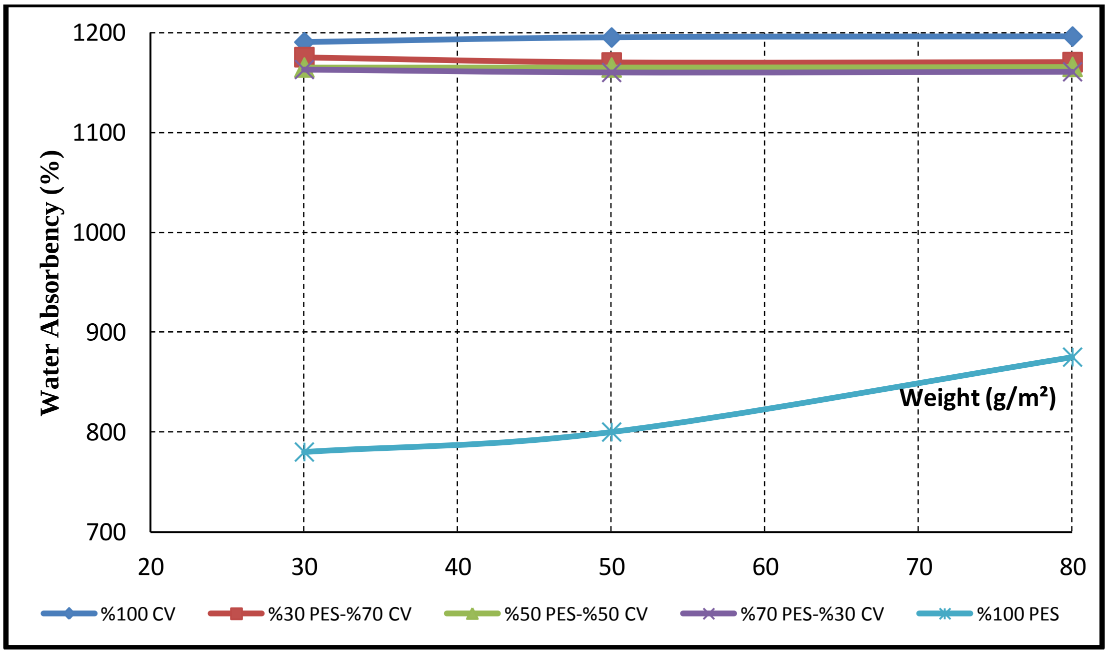

Figure 4.16. Absorbency exchange in different weight for blend Ratio (%PES-%CV)

The effect of blend fiber on absorbency capacity value was found (P ≤ 0.01) at 1% significance level based on the ANOVA table, V70 (70% CV-30% PES) and V30 (30% CV 70% PES) values were found out 5 % significance level (Table 4.20).

Table 4.20. ANOVA Table blend fiber effect on absorbency capacity

		Sum of Squares	df	Mean Square	F	Sig.
v100	Between Groups	144.444	2	72.222	22.887	0.000
	Within Groups	47.333	15	3.156		
v70	Between Groups	90.778	2	45.389	7.537	0.005
	Within Groups	90.333	15	6.022		
v50	Between Groups	60.111	2	30.056	10.525	0.001
	Within Groups	42.833	15	2.856		
v30	Between Groups	48.111	2	24.056	7.705	0.005
	Within Groups	46.833	15	3.122		
v0	Between Groups	48344.778	2	24172.389	8989.731	0.000
	Within Groups	40.333	15	2.689		

The effect of weight on absorbency capacity was found to be significant (P ≤ 0.01) at 1% significance level based on the ANOVA table. (Table 4.21)

Table 4.21. ANOVA Table effect of weight on absorbency capacity

		Sum of Squares	df	Mean Square	F	Sig.
W30	Between Groups	760688.533	4	190172.133	50938.964	0.000
	Within Groups	93.333	25	3.733		
	Total	760781.867	29			
W50	Between Groups	450157.800	4	112539.450	32842.252	0.000
	Within Groups	85.667	25	3.427		
	Total	450243.467	29			
W80	Between Groups	390153.467	4	97538.367	9852.360	0.0
	Within Groups	247.500	25	9.900		
	Total	390400.967	29			

Regarding with Absorbency time

The effect of blend fiber on absorbency time exchange was given in Figure 4.18. It can be notified that there is a direct proportional between the polyester ratio and absorbency time but correlation between weight and absorbency time is fairly poor. There was no important difference between absorbency time and in the same blend fiber, however, the absorbency time got longer when the polyester ratio was increased in the same weight. When hydrophilic property was increased the absorbency time decreased. In other word as the viscose ratio was increased, the absorbency time decreased. The quickest absorbency time was obtained with 100% viscose, and the highest absorbency time was obtained 100% polyester. Figure 4.17 represents effect of weight on absorbency time, as noticed that when unit weight was increased the time for absorbency increased little bit, there was a little variation absorbency time in same weight, that's why it can be inferred that effect of the weight was so less on the absorbency time the highest value of absorbency time was obtained with 80 g/m ² and 100% polyester, and the lowest one was obtained with 30 g/m ² and %100 viscose.

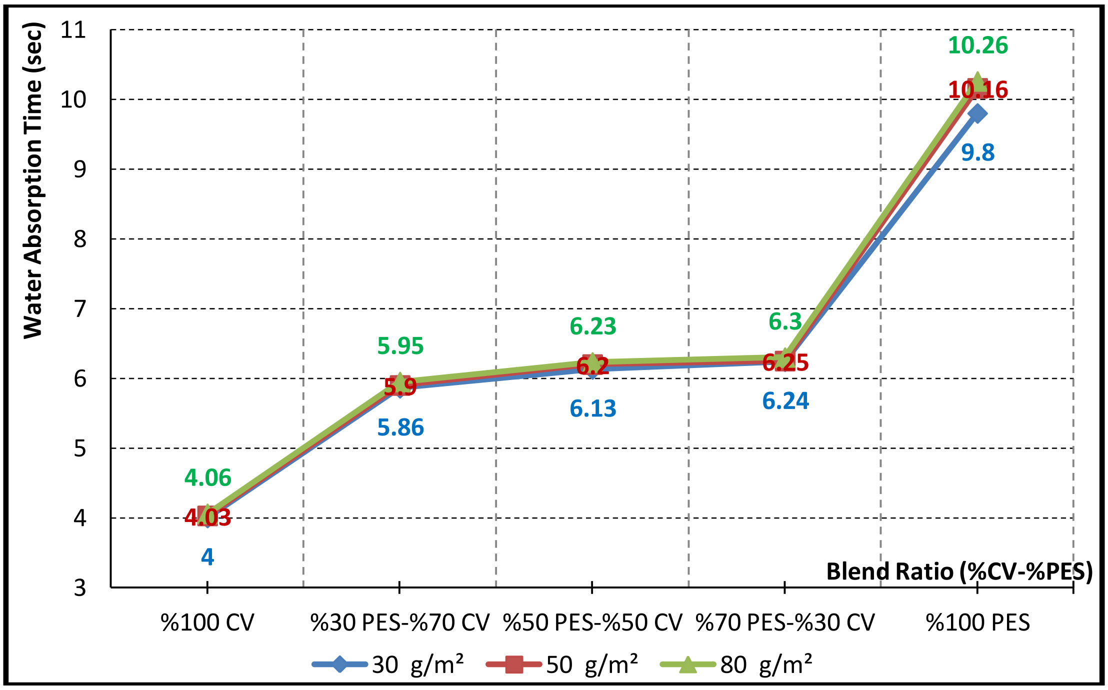

Figure 4.17. Absorbency time exchanges in different blend fiber for 30-50-80 g/m²

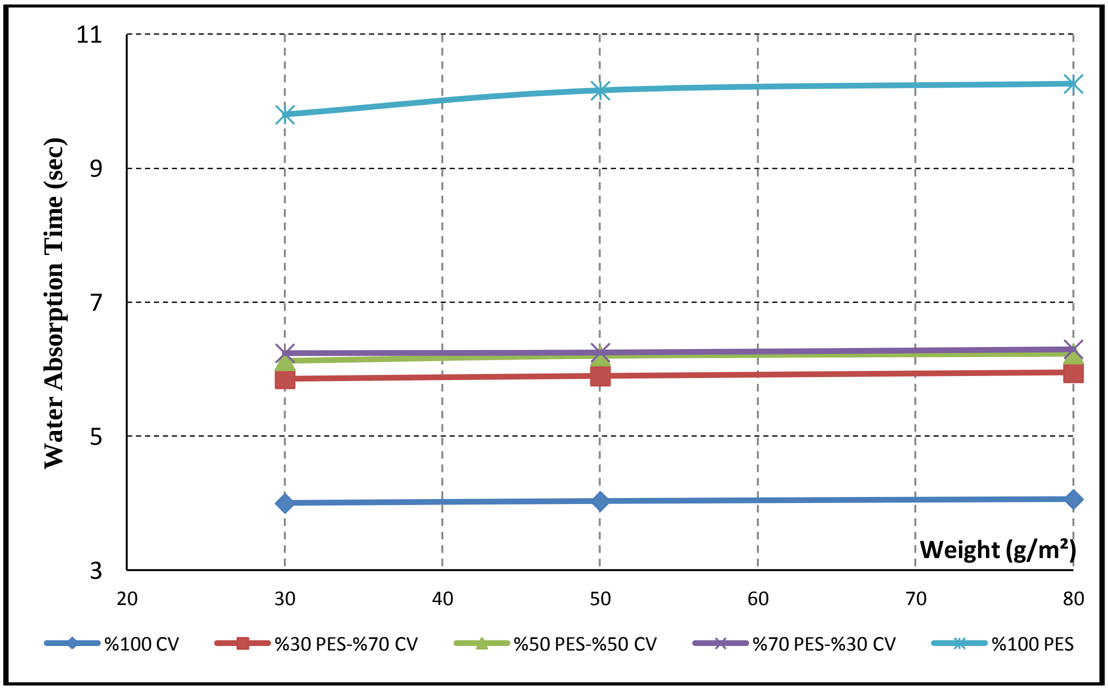

Figure 4.18. Absorbency time exchange in different weight for blend ratio

The effect of blend fiber on absorbency time value was found in significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table (Table 4.22).

Table 4.22. ANOVA Table blend fiber effect on absorbency time

		Sum of Squares	df	Mean Square	F	Sig.
v100	Between Groups	0.007	2	0.004	27.017	0.000
v70	Between Groups	0.029	2	0.015	12.167	0.001
v50	Between Groups	0.032	2	0.016	85.731	0.000
v30	Between Groups	0.012	2	0.006	11.268	0.001
v0	Between Groups	0.732	2	0.366	566.807	0.000

The effect of weight on absorbency time value was found to be significant ($P \leq 0.01$) at 1% significance level based on the ANOVA table. (Table 4.23)

Table 4.23. ANOVA Table effect of weight on absorbency time

		Sum of Squares	df	Mean Square	F	Sig.
W30	Between Groups	105.572	4	26.393	39761.186	0.000
W50	Between Groups	120.047	4	30.012	42190.815	0.000
W80	Between Groups	122.852	4	30.713	126103.478	0.000

4.8. The Result of Whiteness Test

The test result of whiteness was given in Table 4.24. Figure 4.19 illustrates effect of blend fiber on whiteness index

Table 4.24. Result of whiteness test

Raw material	Weight (g/m²)	CIE Whiteness index
100% CV	30	72.44
30% PES-70% CV	30	72.96
50% PES-50% CV	30	73.58
70% PES-30% CV	30	73.87
100% PES	30	73.93
100% CV	50	76.02
30% PES-70% CV	50	76.32
50% PES-50% CV	50	76.44
70% PES-30% CV	50	76.55
100% PES	50	76.65
100% CV	80	77.25
30% PES-70% CV	80	77.33
50% PES-50% CV	80	77.48
70% PES-30% CV	80	77.61
100% PES	80	78.61

It is illustrated that there is direct proportion between polyester and whiteness index, when polyester ratio was increased, whiteness value increased, this was caused from the physical properties of polyester fiber due to white and clean in comparison with viscose. As well as it is not necessary to apply bleaching operation before dying [47]. The highest whiteness index value was obtained with 100% polyester, and the lowest value was obtained with 100% viscose.

Figure 4.20 shows effect of weight on whiteness index. As we mentioned in effect of blend fiber on whiteness, amount of polyester is directly related to whiteness index. It was determine when unit weight was increased the polyester amount increased, hence whiteness value increased. The highest value of whiteness index was obtained 80 g/m ² and the lowest one is 30 g/m ².

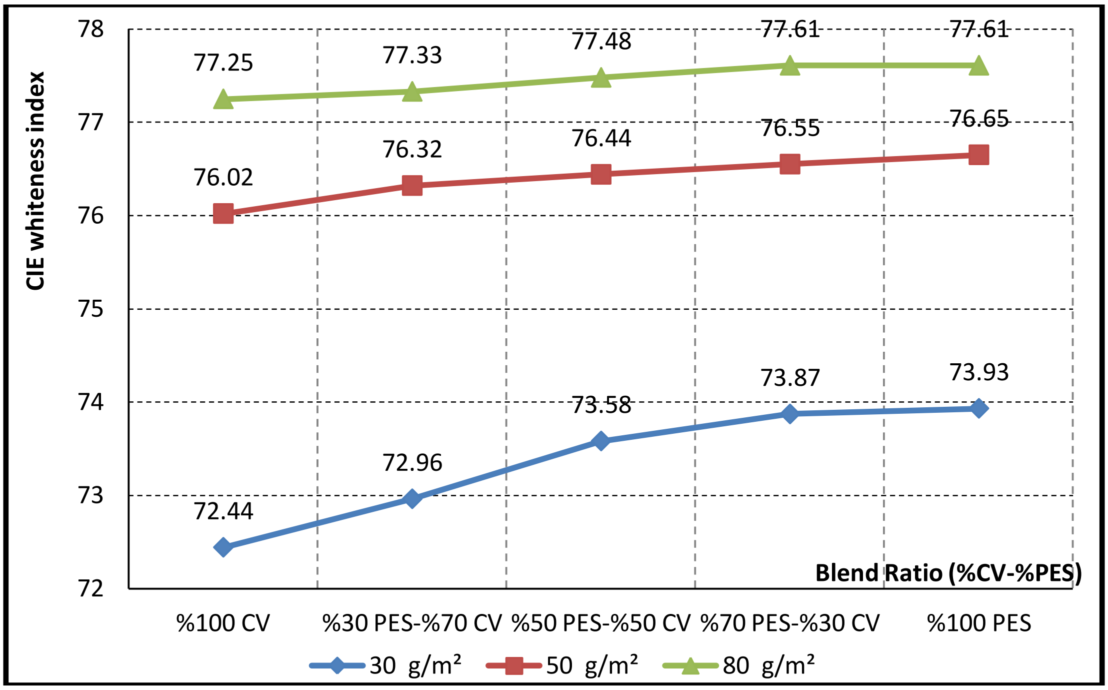

Figure 4.19. Whiteness exchange in different blend fiber for 30-50-80 g/m ²

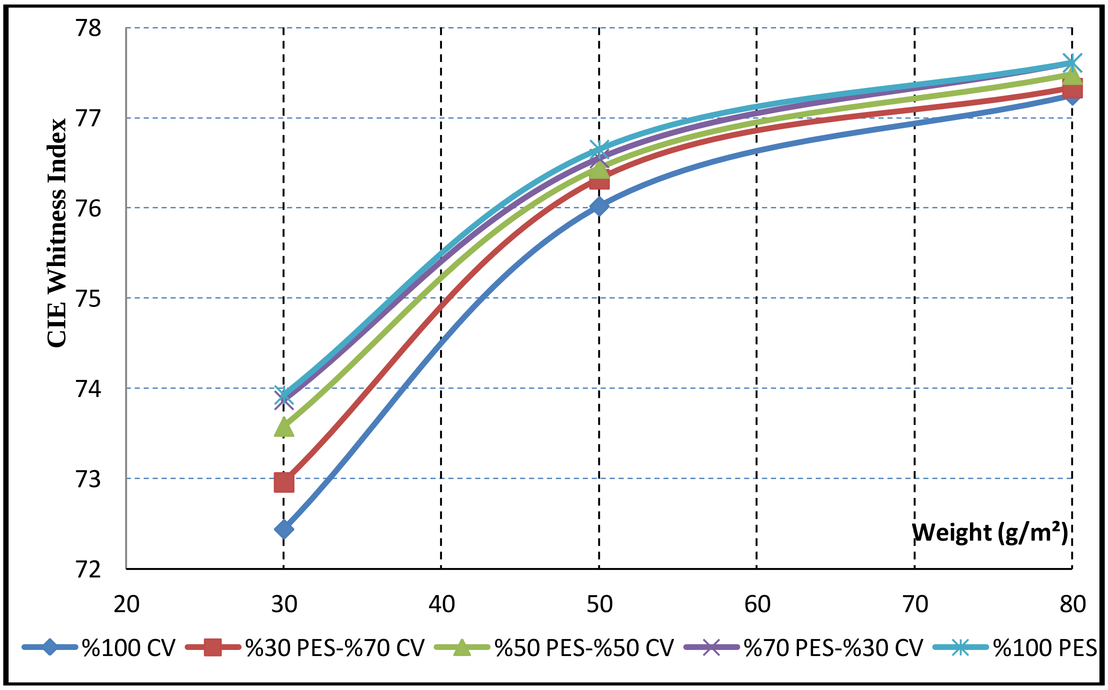

Figure 4.20. Whiteness exchange in different weight for blend ratio (%CV-%PES)

The effect of blend fiber on different blend fiber value was found to be significant (P ≤ 0.01) at 1% significance level based on the ANOVA Table (Table 4.25).

Table 4.25. ANOVA Table effects of blend fiber on whiteness

		Sum of Squares	df	Mean Square	F	Sig.
v100	Between Groups	74.931	2	37.465	117079.375	0.000
	Within Groups	0.005	15	0.000		
	Total	74.936	17			
v70	Between Groups	62.813	2	31.407	98145.625	0.000
	Within Groups	0.005	15	0.000		
	Total	62.818	17			
v50	Between Groups	48.942	2	24.471	76472.500	0.000
	Within Groups	0.005	15	0.000		
	Total	48.947	17			
v30	Between Groups	44.587	2	22.294	69667.500	0.000
	Within Groups	0.005	15	0.000		
	Total	44.592	17			
v0	Between Groups	73.325	2	36.662	98202.857	0.000
	Within Groups	0.006	15	0.000		
	Total	73.330	17			

The effect of weight on whiteness was found to be significant (P ≤ 0.01) at 1% significance level based on the ANOVA Table (Table 4.26).

Table 4.26. ANOVA Table effect of weight on whiteness

		Sum of Squares	df	Mean Square	F	Sig.
W30	Between Groups	9.838	4	2.460	5912.452	0.000
	Within Groups	0.010	25	0.000		
	Total	9.849	29			
W50	Between Groups	9.272	4	2.318	7243.687	0.000
	Within Groups	0.008	25	0.000		
	Total	9.280	29			
W80	Between Groups	7.286	4	1.821	7115.156	0.000
	Within Groups	0.006	25	0.000		
	Total	7.292	29			

4.9. Correlation Analyses

A result of correlation analysis was given in Table 4.27.

Table 4.27. Result of correlation analyses

	TH	TMD	TCD	EMD	ECD	TRMD	TRCD	ACap	ATime	WH
TH	1									
TMD	0.942(**)	1								
TCD	0.914(**)	0.986(**)	1							
EMD	0.451(**)	0.606(**)	0.610(**)	1						
ECD	0.629(**)	0.761(**)	0.762(**)	0.935(**)	1					
TRMD	0.849(**)	0.955(**)	0.943(**)	0.686(**)	0.777(**)	1				
TRCD	0.846(**)	0.938(**)	0.923(**)	0.663(**)	0.742(**)	.0.981(**)	1			
ACap	-0.134	-0.33 (**)	-0.35(**)	-0.601(**)	-0.640(**)	-0.349(**)	-0.285(**)	1		
ATime	0.220(*)	0.468(**)	0.488(**)	0.835(**)	0.835(**)	0.522(**)	0.474(**)	0.816(**)	1	
WH	0.949(**)	0.895(**)	0.883(**)	0.491(**)	0.663(**)	0.770(**)	0.745(**)	-0.176	0.289(**)	1

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

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

TH: Thickness; TMD: Tensile Md; TCD: Tensile Cd; EMD: Elongation At Break Md, ECD: Elongation At Break CD; TRMD: Tear Resistance Md; TRC: Tear Resistance Cd; Acap: Absorbency Cap.; Atime: Absorbency Time; WH: Whiteness

Correlation analyses results;

According to Table 4.27 it was illustrated that thickness was correlated between elongations at breaking MD and CD, tear resistance MD and CD, tensile strength MD and CD, and whiteness, as significant at the level 0.01. Yet there was no correlation between absorbency capacities. As mentioned above, thickness was increased by increasing weight and polyester ratio.

Regarding with tensile strength MD, it was demonstrated that there was no correlation between absorbency capacity and absorbency time. Correlation analyses were showed that increasing weight fabric caused increasing the tensile strength MD. In addition direct proportion was obtained with thickness, elongation at breaking, tear resistance, and whiteness as significant at the level 0.01 hence the tensile strength was influenced positively except absorbency capacity and time. Also tensile strength CD was similar to tensile strength MD.

Based on Table 4.27 correlation analyses it was showed that the elongation at breaking both MD and CD is correlation between tensile strength MD and CD, thickness, tear resistance MD and CD, absorbency capacity and time as significant at the level 0.01. It was obtained that tear resistance MD correlated between tensile strength MD and CD, elongation at Break MD and CD, thickness, absorbency capacity and absorbency time as significant at the level 0.01.

According to Table 4.27 it was observed that tear resistance CD was similar to tear resistance MD; there was a correlation between tensile MD and CD, elongation at Break MD and CD, thickness, absorbency capacity and absorbency time as significant at the level 0.01. According to Table 4.27 absorbency capacity value was different than others, because absorbency capacity is declined by polyester ratio unlike, other performance properties are increased by polyester ratio, that was the reason absorbency capacity was showed on the table as minus (-). There was a correlation between and absorbency time, tensile strength MD and CD tear resistance MD and CD, also elongation at break MD and CD, but there was no correlation between thicknesses and whiteness. All Correlation was found significant at the 0.01 level.

Regarding with absorbency time, as mentioned in above section, it was increased by polyester ratio. According to Table 4.27 it was exhibited that there was a correlation between absorbency, tensile strength MD and CD, tear resistance CD, elongation at breaking MD and CD, whiteness as significant at the level 0.01 Also thickness was as significant at the level 0.05. It was illustrated the Table 4.27 whiteness was related to polyester ratio as we mentioned in above, there is a correlation between tear resistance MD and CD, elongation at break MD and CD, tensile strength CD and MD absorbency time as significant at the level 0.01, yet there was no correlation between absorbency capacity.

4.10. Regression Analyses

Regression analyzes was investigated relationship between weight, blend fiber and performance tests. For this purposes regression analyses was performed for all performance tests separately, and according to result the magnitude and sign of the coefficients of terms shows that it was given information about influence on performance [48]. Fore example, thickness value was dependent (+) 0.06 weight and (-) 0.01 fiber. Weight was more influence than blend fiber on thickness, and sign minus or positive means, thickness was increased by weight and decreased by change blend fiber.

4.10.1. Dependent Variable: Thickness

Table 4.28. Coefficients table for thickness

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	0.306	0.008		39.023	0.000
	Weight	0.006	0.000	0.967	51.126	0.000
	Fibers	-0.001	0.000	-0.185	-9.800	0.000

According to SPSS 15.0 program, the regression analyzes was done for thickness value by coefficient table in order to evaluate performance value (Table 4.28). Thickness equation was calculated as below.

TH=0.306 + 0.06*Weight - 0.01 Fiber (4.1)

TH: Thickness

Weight: 30-50-80 m^2

Fiber: 100% Polyester, 30% Polyester-70% Viscose. 50% Polyester 50% Viscose, 30% Polyester 70% Viscose, 100% Viscose

According to Eq. (4.1) it was illustrated that there was a direct proportion between weight and thickness also inverse proportion with blend fiber and thickness. In addition the effect of weight was found greater than the effect of blend fiber on thickness value. Further information was given in appendix part for regression analyzes of thickness.

4.10.2. Dependent Variable: Tensile Strength MD

Table 4.29. Coefficients table for tensile strength in MD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	10.436	6.277		1.663	0.100
	Weight	2.470	0.097	0.863	25.433	0.000
	Fibers	-0.681	0.059	-0.394	-11.615	0.000

According to SPSS 15.0 program, the regression analyzes was done by coefficient table (Table 4.29). Tensile strength MD equation is as below.

TMD=10.436+2.470*weight --0.681*fibers (4.2)

TMD: Tensile Strength MD

Weight: 30-50-80 m^2

Fiber: blend fiber ratio

Thanks to Eq. (4.2) it was obtained there was a direct proportion between weight and tensile strength MD also inverse proportion blend fiber and tear strength MD. According to this equation, it was demonstrated that weight was greater effect than blend fiber on tensile strength MD, further information was given in appendix part for regression analyzes of tensile strength.

4.10.3. Dependent Variable: Tensile Strength CD

Table 4.30. Coefficients table for tensile strength in CD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	4.377	1.955		2.239	0.028
	Weight	0.563	0.030	0.816	18.606	0.000
	Fibers	-0.170	0.018	-0.409	-9.332	0.000

According to SPSS 15.0 program, regression analyzes was done by coefficient table (Table 4.30). Tensile strength CD equation was calculated as below.

TCD= 4.377 + 0.563*weight -0.170*Fiber (4.3)

TCD: Tensile Strength CD

Weight: 30-50-80 m^2

Fiber: Blend fiber ratio

Based on Eq. (4.3) it was noticed that there was a direct proportion between weight and tensile strength CD also inverse proportion with blend fiber and tensile strength CD. As well as the effect of weight was obtained greater than the effect of blend fiber on tensile strength CD. Further information was given in appendix part for regression analyzes of tensile strength CD.

4.10.4. Dependent Variable: Elongation at Break MD

Table 4.31. Coefficients table for elongation at break in MD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	46.655	0.507		91.991	0.000
	Weight	0.108	0.008	0.293	13.805	0.000
	Fibers	-0.208	0.005	-0.935	-44.023	0.000

According to SPSS 15.0 regression analyzes was done by coefficient table (Table 4.31). The equation of Elongation at break was calculated as below.

EMD=46.655+0.108* Weight -0.208*Fiber (4.4)

EMD: Elongation at Break MD

Weight: 30-50-80 m^2

Fiber: Blend fiber ratio

Eq. (4.4) was demonstrated that there was a direct proportion between weight and elongation at break MD also inverse proportion with blend fiber and elongation at break MD, according to this equation the effect of blend fiber it was found greater than the effect of weight on elongation at break. Further information in appendix part for regression analyzes of elongation at break MD.

4.10.5. Dependent Variable: Elongation at Break CD

Table 4.32. Coefficients table for elongation at break in CD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	156.586	0.719		217.728	0.000
	Weight	0.221	0.011	0.477	19.848	0.000
	Fibers	-0.238	0.007	-0.850	-35.382	0.000

According to SPSS 15.0 program, regression analyzes was done by coefficient table (Table 4.32). Equation for elongation at breaking CD prediction was calculated as below.

ECD=156.586+0.221*weight-0.238*fibers (4.5)

ECD: Elongation at Break CD

Weight: 30-50-80 m^2

Fiber: Blend fiber ratio

Eq. (4.5) was demonstrated that there was a direct proportion between weight and elongation at break CD also inverse proportion with blend fiber and elongation at break CD, also blend fiber was noticed greater effect than weight on elongation at break CD according to this equation, further information was given in appendix part for regression analyzes of elongation at break CD.

4.10.6. Dependent Variable: Tear Resistance MD

Table 4.33. Coefficients table for tear resistance in MD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	8.538	6.043		1.413	0.161
	Weight	1.524	0.094	0.751	16.297	0.000
	Fibers	-0.614	0.056	-0.501	-10.884	0.000

According to SPSS 15.0 program, regression analyzes was done by coefficient table (Table 4.33) Tear resistance MD equation can be seen as below.

TRMD=8.538+ 1.524*weight -0.614*fibers (4.6)

TRMD: Tear Resistance MD

Weight: 30-50-80 m^2

Fiber: Blend fiber ratio

Eq. (4.6) was illustrated that there was a direct proportion between weight and tear resistance MD also inverse proportion with blend fiber and tear resistance MD, in addition effect of weight was found greater effect than blend fiber on tear resistance in MD according to this equation, further information was given in appendix part for regression analyzes of tear resistance MD.

4.10.7. Dependent Variable: Tear Resistance CD

Table 4.34. Coefficients table for tear resistance in CD

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	4.557	1.434		3.178	0.002
	weight	0.365	0.022	0.769	16.436	0.000
	fibers	-0.134	0.013	-0.467	-9.991	0.000

According to SPSS 15.0 program, the regression analyzes was done by coefficient table (Table 4.34). The equation of tear resistance CD was seen as below

TRCD=4.557+ 0.365*weight -0.134*fibers (4.7)

TRCD: Tear Resistance CD

Weight: 30-50-80 $m^{2.}$

Fiber: Blend fiber ratio

Eq.(4.7) was showed that there was a direct proportion between weight and tear resistance CD and inverse proportion with blend fiber and tear resistance CD. As well as effect of weight was obtained greater effect than effect of blend fiber on tear resistance in CD according to this equation, further information was given in appendix part for regression analyzes of tear resistance CD.

4.10.8. Dependent Variable: Absorbency Capacity

According to SPSS 15.0 program, absorbency capacity of regression analyzes was done by coefficient table. (Table 4.35), according to this table the equation of water absorbency was calculated as below.

Table 4.35. Coefficients table for absorbency capacity

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	961.770	37.207		25.849	0.000
	weight	0.165	0.576	0.022	0.286	0.775
	fibers	3.010	0.347	0.681	8.667	0.000

ACap=961.770+ 0.165*weight + 3.010*fibers (4.8)

ACap: Absorbency Capacity

Weight: 30-50-80 m^2

Fiber: Blend fiber Ratio

Regarding with Eq. (4.8) it was seen there was a direct proportion between weight and absorbency time and also blend fiber. Further more, the effect of blend fiber was found greater than the effect of weight on absorbency capacity. Further information about regression analyzes was given in appendix part.

4.10.9. Dependent Variable: Absorbency time

Table 4.36 Coefficients table for absorbency time

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	8.995	0.257		35.049	0.000
	Weight	0.003	0.004	0.031	0.755	0.453
	Fibers	-0.053	0.002	-0.922	-22.239	0.000

According to SPSS 15.0 regression analyses was done by coefficient table for absorbency time. The equation of absorbency time was calculated as below.

ATime = 8.995+0.003*weight – 0.053*fibers (4.9)

ATime: Absorbency Time

Weight: 30-50-80 m^2

Fiber: Blend fiber Ratio

According to Eq. (4.9) was showed that there was a direct proportion between weight and absorbency time, also inverse proportion with blend fiber and absorbency time. In addition the effect of blend ratio was found greater than the effect of weight on absorbency time. Further information was given in appendix part.

4.10.10. Dependent Variable: Whiteness

Table 4.37. Coefficients table for whiteness

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	72.221	0.251		287.201	0.000
	weight	0.082	0.004	0.883	21.074	0.000
	Fibers	-0.015	0.002	-0.259	-6.179	0.000

According to SPSS 15.0 program, regression analyzes was done by coefficient table. Whiteness equation was calculated as below;

WH: 72.221 +0.082*weight -0.015*fibers (4.10)

WH: Whiteness

Weight: 30-50-80 m^2

Fiber: Blend fiber Ratio

Eq. (4.10) was showed that there was direct proportion between weight and whiteness, and also inverse proportion blend fiber and whiteness. The effect of weight was obtained greater than the effect of blend fiber on whiteness.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

In this study, influence of polyester / viscose blend fiber and weight on spunlace nonwoven fabric was investigated and evaluated by means of statistical analysis, for this purposes five different blend fibers and three different weights nonwoven fabrics were examined under the textile laboratory through experiments in order to determine the performance properties.

In this thesis, type of fibers were selected as the most commonly used fibers both polyester and viscose fibers, and examined as following performance properties.

- **Thickness**
- **Tensile Strength**
- **Elongation at Break**
- **Tear Resistance**
- **Absorbency Capacity**
- **Absorbency Time**
- **Whiteness**

Process which performed in this study was summarized as below

1. First part of thesis, research of literature was performed, and thanks to this literature studying it was determined what kind of process should be chosen about nonwoven fabrics.
2. Regarding thesis subject, spunlace process which was produced by viscose and polyester blend fibers were decided. Samples were obtained from Mogul Nonwoven Textile Company and samples were taken five different blend fiber 100% Polyester, 30% Polyester-70% Viscose. 50% Polyester 50% Viscose, 30% Polyester 70% Viscose, 100% Viscose three different weight.

3. The samples were tested in their own laboratory in Mogul Nonwoven Textile Company, and also in Gaziantep University textile laboratory.
4. According to result of laboratory examination, it was prepared graphic and table list to explain the point of performance properties spunlace fabrics. Also we used SPSS 15.0 to have confirmation and comparison value with taking from laboratory examination.
5. Regarding with statistical analyzes, first of all, it was determined model by means of regression analyzes, compared the tests whether results are at significance levels of $\alpha \leq 0.05$ and $\alpha \leq 0.01$ by means of ANOVA. Also prepared equation in order to interpret performance properties through regression analyzes and examined correlation analyzes between all performance tests.

5.1. Conclusion of Studying

5.1.1. Conclusion of statistical analyzes

Regarding with statistical analyzes, all performance properties were examined by statistical analyzes through SPSS 15.0 program. All experimental result was investigated the influence on terms of weight and blend fiber through ANOVA table. According to ANOVA Table all performance of properties fabric was obtained the of $P \leq 0.05$ and $P \leq 0.01$ at 1% and 5% significance level in blend fiber and weight effect on performance properties. (Table 5.1)

Table 5.1. ANOVA Tables exchange of blend fiber and weight on performance properties

	Significance							
PERFORMANCE TESTS	**V100**	**V700**	**V50**	**V30**	**V0**	**W30**	**W50**	**W80**
Thickness	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tensile Strength MD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tensile Strength CD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Elongation at Breaking MD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Elongation at Breaking CD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tear Resistance MD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tear Resistance CD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Water Absorbency Cap.	0.000	0.005	0.001	0.005	0.000	0.000	0.000	0.000
Water Absorbency Time	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Whiteness	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Tukey table was used in ANOVA tables in order to attain the best value of performance properties, According to Tukey Table five different blend fibers100% Polyester, 30% Polyester 70% Viscose 50% Polyester 50% Viscose, 30% Polyester 70% Viscose, 100% Viscose and three different weight 30 g m^2 50 gm^2 and 80 gm^2 were examined.

Table 5.2. Highest and lowest value for performance properties in Tukey Table

Test	The Highest Value	The Lowest Value
Thickness	80 g 100% PES	30 g 100 % CV
Tensile Strength MD	80 g 100% PES	30 g 100% CV
Tensile Strength CD	80 g 100% PES	30 g 100 % CV
Elongation at Breaking MD	80 g 100% PES	30 g 100 % CV
Elongation at Breaking CD	80 g 100% PES	30 g 100 % CV
Tear Resistance MD	80 g 100% PES	30 g 100 % CV
Tear Resistance CD	80 g 100% PES	30 g 100 % CV
Water Absorbency Cap.	50, 80 g 100% CV	30 g 100 % PES
Water Absorbency Time	80 g 100% CV	30 g 100 % PES
Whiteness	80 g 100% PES	30 g 100% CV

Table 5.2 is represent the highest and the lowest value for performance properties, this table was obtained comparison with all weight and blend fiber through TUKEY table and also correlation analyzes, it was depicted that the best value for thickness was obtained by 80 g 100% polyester, for tensile strength 80 g 100% polyester, for elongation at break 80 g 100 % polyester, for tear Resistance 80 g 100 % polyester, for absorbency capacity 30, 50, 80 g 100% viscose, for absorbency time 100 % viscose, for whiteness 80 g 100 % polyester, and the lowest as it seen the table. Further information in Appendix A statistical analyzes result for experimental study.

According to Correlation analyzes thickness was correlated between elongations at breaking MD and CD, tear resistance MD and CD, tensile strength MD and CD, and whiteness, absorbency time yet there was no correlation between absorbency capacity. Tensile strength MD and CD was correlation between thickness, elongation at breaking, tear resistance, and whiteness water absorbency. Elongation at breaking both MD and CD has correlation between tensile strength MD and CD, thickness, tear resistance MD and CD, water absorbency, and time. Tear resistance MD was correlation between tensile strength MD and CD, elongation at Break MD and CD, thickness, absorbency capacity and absorbency time. Tear resistance CD was similar to tear resistance MD; there was a correlation between tensile MD and CD, elongation at Break MD and CD. Absorbency capacity there was a correlation between and water absorbency time, tensile strength MD and CD, tear resistance MD and CD, also elongation at break MD and CD, but there was no correlation between thicknesses. For water absorbency time there was a correlation between water absorbency, tensile strength MD and CD, tear resistance CD, elongation at breaking MD and CD. For whiteness there was a correlation between tear resistance MD and CD, elongation at break MD and CD, tensile strength CD and MD, yet there was no correlation between water absorbency.

The result of this study for regression equation was calculated as below, in the equation was pointed out TH means thickness, TMD was tensile strength MD, TCD was tensile strength CD, EMD was elongation at break MD, ECD was elongation at break CD, TRMD was tear resistance MD, TRCD was tear resistance CD, ACap was water absorbency, A time was water absorbency time and WH was whiteness. (Table 5.4)

Table 5.3. Regression analyzes and equations

Performance	Regression equation
Thickness	TH=0.306 + 0.06*Weight - 0.01 Fiber
Tensile Strength (MD)	TMD=10.436+2.470*weight --0.681*fibers
Tensile Strength (CD)	TCD= 4.377 + 0.563*weight -0.170*Fiber
Elongation At Break MD	EMD=46.655+0.108* Weight -0.208*Fiber
Elongation At Break (CD)	ECD=156.586+0.221*weight-.238*fibers
Tear Resistance (MD)	TRMD=8.538+ 1.524*weight -0.614*fibers
Tear Resistance (CD)	TRCD=4.557+ 0.365*weight -0.134*fibers
Water Absorbency Cap.	ACap=961.770+ 0.165*weight + 3.010*fibers
Water Absorbency Time	ATime = 8.995+ 0.003*weight – 0.53*fibers
Whiteness	WH: 72.221 + 0.82*weight -0.15*fibers

Weight: 30-50-80 m^2

Fiber: 100% Polyester, 30% Polyester 70% Viscose, 50% Polyester 50% Viscose, 30% Polyester 70% Viscose, 100% Viscose

According to regression equation, it was concluded as below result

- ✓ Effect of weight was found greater than the effect of blend fiber on thickness value.

- ✓ Effect of weight was obtained greater effect than blend fiber on tensile strength in MD and CD.
- ✓ Effect of blend fiber was obtained greater than the effect of weight on elongation at break in MD and CD.
- ✓ Effect of weight was found greater effect than blend fiber on tear resistance in MD and CD.
- ✓ Effect of blend fiber was obtained greater than effect of weight on absorbency capacity.
- ✓ Effect of blend ratio was obtained greater than the effect of weight on absorbency time.
- ✓ Effect of weight was found greater than effect of blend fiber on whiteness.

5.1.2 Conclusion of the effect of weight and blend fiber

In this study it was examined as following.

- ✓ The effect of different blend fiber on performance properties.
- ✓ The effect of different weight on performance properties.

5.1.2.1 The effect of different blend fiber on and performance properties

Table 5.4. Blend fiber effect on performance properties

Blend Fibers	100CV/ 70CV-30P	70CV-30P/ 50CV-50P	50CV50P/ 30Cv-70P	30CV-70P/ 100P
Thickness	+	+	+	+
T.Strength and Elong. (MD)	+	+	+	+
T. Strength and Elong.(CD)	+	+	+	+
Tear Resistance MD	+	+	+	+
Tear Resistance CD	+	+	+	+
Absorbency Capacity	-	-	-	-
Absorbency Time	+	+	+	+
Whiteness	+	+	+	+

- ✓ Table 5.4 was illustrated that the thickness of the nonwoven fabric samples was influenced positively by polyester value increase. This is caused from being difference of pack ability between polyester and viscose fibers.
- ✓ Tensile strength increased in MD and CD by increasing polyester ratio due to the polyester is stronger and more elongation ability than viscose.

- ✓ When polyester amount was increased, tear resistance increased due to the fact that polyester fiber is more flexible than viscose. This made the nonwoven fabrics includes more polyester fiber more resistive to the tear force. The structure of viscose is rigid and fragile. And so, fabric samples including high ratio viscose fiber are less resistive to the tear force.
- ✓ Viscose fiber has got high absorbency capacity than polyester fibers. As the ratio of polyester was increased, the absorbency capacity of the fabric sample decreased, however thanks to the new chemical application and hydrophilic, even though polyester fiber`s absorbency capability is so less, it can be good absorbency ability by means of hydrophilic process.
- ✓ When polyester ratio was increased, absorbency time increased. Viscose fiber can absorb water pretty quickly, but polyester can not.
- ✓ There is a direct proportion between polyester ratio and whiteness index. When the polyester ratio was increased, the whiteness index value increased due to the polyester fiber has more whiter than viscose fiber.

5.1.2.2 The effect of different weight on performance properties

Table 5.5. Effect of different weight on performance properties

Fiber ratio	**100CV**		**70CV-30P**		**50CV-50P**		**30CV-70P**		**100P**	
Weight(g/m^2)	30-50	50-80	30-50	50-80	30-50	50-80	30-50	50-80	30-50	50-80
Thickness	+	+	+	+	+	+	+	+	+	+
T. Strength & Elong MD	+	+	+	+	+	+	+	+	+	+
T. Strength & Elong. CD	+	+	+	+	+	+	+	+	+	+
Tear Resistance MD	+	+	+	+	+	+	+	+	+	+
Tear Resistance CD	+	+	+	+	+	+	+	+	+	+
Absorbancy Capacity	+	+	+	+	+	+	+	+	+	+
Absorbency Time	+	+	+	+	+	+	+	+	+	+
Whiteness	+	+	+	+	+	+	+	+	+	+

According to Table 5.5 it was conclude that

- ✓ The thickness was increased with increasing weight 30-50-80 g/m^2. This situation was caused the fibers amount increased in the structure, therefore made fiber thicker.
- ✓ Tensile strength and elongation were increased by increasing unit weight in MD and CD, as it was known that when the unit weight was increased, the fibers were exposed to more stress and strain.

- ✓ Tear resistance increased by increasing unit weight in MD and CD similar to tensile strength, when the weight was increased in the cross-sectional area of the samples, the stress-strain increased continuously until the sample tear up.
- ✓ Absorbency capacity was increased by increasing the unit weight due to the cross section increased in per unit area.
- ✓ Absorbency time increased by increasing unit weight. That is the reason when the mass unit was increased, there much more area to absorb it, hence absorbency time increases.
- ✓ The whiteness increased by increasing unit weight, due to amount of polyester increased in all blend ratios.

5.2. Recommendations for further studying

In this thesis we examined spunlace fabric and endeavored to have scientific research about spunlace performance and psychical characterization and properties, however this studying might not be satisfied or give answer directly for further purposes, for this reason we can give some recommendation for further studying.

The further study on this subject may be worked out as follows:

- Different fibers may be used rather than polyester and viscose fibers.
- In order to get different ability such as fireproof, anti-bacterial, for the nonwoven fabric, it can be used different ending process.
- Additional bonding techniques for spunlace can be researched, noticeably through-air bonding, calendaring, and perhaps chemical bonding.
- Spunlace can be used as apparel, bed covering, weather-resistant apparel, clean-suits, filters car covers, shoe lining, acoustic enhancement/damping, electronic packaging, etc.
- In order to decrease costing price and prolong the life span it can be produced by pulp or it can be added in blend fiber. Pulp is a lignocelluloses fibrous material from wood, fiber crops [49].
- In order to rise up the strength capability it can be used different technology such as spun bond technology.

REFERENCES

[1] Duran, K. (2004). Dokusuz Yüzeyler-Tafting Nonwoven Yapıştırma Malimo, Teknik Fuarcılıkltd. Şti. İstanbul.

[2] Patel, M., Bhrambhatt, D. (2008). A Review on Nonwoven Fabrics Used in Apparel. TeLxtile Technology M.S. University: Vadodara.

[3] Cook, J.G., Shildon, G. (1984). Handbook of Textile Fibres Manmade Fibers. 5th edition. Universty of Cornell New York: Merrow.

[4] White, C.F. (1990). Hydroentanglement Technology Applied to Wet-formed and other precursor webs. *Tappi Journal*. **73,** 187-192.

[5] Moore, G. (1988). Aspects of Nonwovens Bonding: The Development and Potential of Hydroentanglement. *Tappi Journal*. **80,** 179-183.

[6] Lichstein, *B.M.* (1988). The Nonwovens Handbook, Association of the Nonwoven Fabrics Industry. New York: INDA.

[7] Vaughn, E. (1978). Spunlaced Fabrics, *Canadian Textile Journal,* 31-36.

[8] Peter, S., Marina, C.C., Jörg, S. (2009). Rainbow: A Novel Viscose Fiber For Pes Blends Innovations In Dyeing Technology Austria: Lenzing.

[9] Kalebek, N.A. (2010). Investigation of Abrasion-Friction and Surface Properties of Nonwoven Fabrics Produced with Different Methods. Ph.D. Thesis, University Of Cukurova, Adana.

[10] Cincik, E. (2010). Experimental and Statistical Analysis of The properties of Polyester/Viscose Blended Nonwovens Produced by Needle Punching Method. Ph.D. Thesis, University Of Cukurova, Adana.

[11] Asgharian, A.A., Hajiani, F. (2010). The Influence of Water Jet Pressure on Absorbency of Spunlace Nonwoven. 7th International Conference TEXSCI 2010, Czech Republic.

[12] Unal, H. (2009). Development of Disposable Hydrophilic and Antibacterial Polypropylene Nonwoven Sheet. Ph.D. Thesis, Istanbul Technical University, Istanbul.

[13] Stahl, J. J. (2010). Study of Hydroentangling on Un-bonded Tyvek Nonwoven Fabric. M.Sc. Thesis, North Carolina State University: Raleigh, North Carolina.

[14] Zheng, H. (2003). The Impact of Input Energy, Fiber Properties, and Forming Wires on the Performance of Hydroentangled Fabrics. Ph.D. Thesis, North Carolina State University: Raleigh, North Carolina.

[15] Malshe, P. (2010). Enhancing Electrostatic Properties and Hydroentangling Efficiency via Atmospheric Plasma Treatment. M.Sc. Thesis, North Carolina State University, Raleigh, North Carolina.

[16] Kennerly, S.P. (2006). The Application of Hydroentangling to Enhance the Mechanical Properties of Woven Jacquards. M.Sc. Thesis, North Carolina State University, Raleigh, North Carolina.

[17] Begenir, A. (2003). The Role of Orifice Design in Hydroentanglement. M.Sc. Thesis, North Carolina State University, Raleigh, North Carolina.

[18] Jahangir, A.S., Shamsuddin, M. (2010). Nonwoven Technology. 1st Edition. Southeast Universty: Textile Bulletin.

[19] Pierre, W. (2008). Nonwovens Vision 2020. Av Herrmann-Debroux 461160 Brussels Belgium: EDANA.

[20] Rory, H. (2009). Italian Trade Mission Association of the Nonwoven Fabrics Industry Italy: Crescent Green, Suite 115.

[21] Giovanni, T. (2009). Nonwoven Technology Textile - Reference Book for Man Made Fibers Italy: Acimit.

[22] EDANA. European Nonwovens and Disposables. (2013). European Nonwovens and Disposables. www.edana.org/Discover Nonwovenshow-they're-made/formation.

[23] www.andritz.com/group/gr-news/gr-news-detail.htm?id=25036. (2013).

[24] EDANA. European Nonwovens and Disposables. (2013). Sustainability Report. www.sustainability.edana.org.

[25] Kamath, M.G., Atul, D., Raghavendra, R. H. (2004). Absorbtion properties. Materials Science & Engineering 554 Course Note, The *University of Tennessee: Knoxvill.*

[26] Mechanical Technology of Nonwovens Department of Nonwovens. (2013) Http://Www.Ft.Tul.Cz/Depart/Knt/Nove/Dokumenty/Studmaterialy/Mtt/Kapitola8_9 Spunlace.Ppt.

[27] Kamath, M.G., Atul, D., Raghavendra, R. H. (2004). Nonwovens Science and Technology. Materials Science & Engineering 554 Course Note, The *University of Tennessee: Knoxvill.*

[28] Ian, B., Francis, J.M., Mord, T. (2012). Hydroentangling Technology Primer, Printing By Design, Raleigh, North Carolina USA: INDA.

[29] Coskun, M.T. (2010). The Investigation of Effects of Viscose Filament Used in Weft to Polyester/Viscose/Elastan Fabric’s Performance Characteristics. M.Sc. Thesis, Çukurova University.

[30] Jinlian, H. (2008). Fabric Testing Number 76. Cambridge England: Wood Head Publishing Limited.

[31] ANDRITZ. (2012). G System Solutions for Nonwovens From Forming To Finishing. www.Andritz.Com/Nonwoven.

[32] Tartimsan.Com/Dosyalar/Site_Resim/Urunler/Kucuk/2678011.Jpg. (2013).

[33] WSP. Worldwide Strategic Partners. (2013). Standard Test Method for Thickness 120.6 (05), EDANA.

[34**]** http://Gantep.Edu.Tr/Ab/Atl_Lab.Php?Id=186&Bolum_Id=107. (2013).

[35] WSP. Worldwide Strategic Partners. (2013). Standard Test Method for Water Absorbency Time 120.6 (05), EDANA.

[36] WSP. Worldwide Strategic Partners. (2013). Standard Test Method for Water Absorbency 10.1 (05), EDANA.

[37] WSP. Worldwide Strategic Partners. (2013). Standard Test Method for Tensile Strength 110.4 (05), EDANA.

[38] WSP. Worldwide Strategic Partners. (2013). Standard Test Method for Tear Resistance 100.2 (05), EDANA.

[39] http://en.wikipedia.org/wiki/Zwick_Roell_Group. (2013).

[40] TAPPI. Technical Association of the Pulp and Paper Industry. (1996). 96 provisional Method, Cie Whiteness and Tint of Paper and Paperboard (Usingd/0º, Diffuse Illumination and Normal Viewing), USA.

[41] CIE. Commission Internationale de L'Eclairage. (1986). Colorimetry Second Edition. Vien Australia: Publication Cie.

[42] Griesser, R. (1995). Assessment of Whiteness and Tint of Fluorescent Substrates with Good Instruments Correlation. *Color Res. Appl*. **6,** 446-460.

[43] Çinçik, E., Koç, E. (2012). Analysis of Air Permeability of Polyester/Viscose Blended Needle-punched Nonwovens. *Textile Research Journal*. **82,** 430-442.

[44] Albrecht, W., Fuchs, H., Kittelmann, W. (2003). Nonwoven Fabrics Raw Materials Manufacture Applications Characteristics Testing Processes. Weinheim: Wiley.

[45] Kalebek, N.A., Babaarslan, O. (2009). Evaluation of Friction and Stiffness Behaviour of Nonwovens Produced with Spunbond and Spunlace Methods. *Journal of Textile and Apparel*. **19,** 145-150.

[46] Tyagi, *G*. K., Gopal, A. (2007). Contribution of fiber profile to performance characteristics of polyester-viscose and polyester-cotton ring and MJS yarns. *Indian Journal of fiber & Textile Research*. **32,** 404-408.

[47] www.tekstilsayfasi.blogspot.comonterbiyeislemleriagartma.html. (2013).

[48] Tarı, R. (1999). Ekonometri, Alfa Basım Yayım Dağıtım Sanayi ve Ticaret Ltd. Şti. İstanbul. 403s.

[49] WIKI. Wikipedia. (2013). http://en.wikipedia.org/wiki/Pulp.

APPENDIX A

STATISTICAL ANALYSIS RESULTS FOR EXPERIMENTAL STUDY

1. Fiber Effects on Thickness In Tukey Table

Table A1. Thickness In Tukey Table for 100% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	10	0.43000		
50sqm	10		0.56600	
80sqm	10			0.72600
Sig.		1.000	1.000	1.000

Table A2. Thickness in Tukey Table for 30% PES-100% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	10	0.43200		
50sqm	10		0.59000	
80sqm	10			0.72900
Sig.		1.000	1.000	1.000

Table A3. Thickness in Tukey Table for 50% PES-50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	10	0.43600		
50sqm	10		0.59600	
80sqm	10			0.74000
Sig.		1.000	1.000	1.000

Table A4. Thickness in Tukey Table for 70% PES-30% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	10	0.45000		
50sqm	10		0.60200	
80sqm	10			0.77400
Sig.		1.000	1.000	1.000

Table A5. Thickness in Tukey Table for 100% PES

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	10	0.46400		
50sqm	10		0.64600	
80sqm	10			0.82600
Sig.		1.000	1.000	1.000

2. Weight effects on Thickness in Tukey table

Table A6. Thickness in Tukey Table for 80g/m^2

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	10	0.72600			
V70	10	0.72900			
V50	10		0.74000		
V30	10			0.77400	
V0	10				0.82600
Sig.		0.914	1.000	1.000	1.000

Table A7. Thickness in Tukey Table for 50g/m^2

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	10	0.56600			
V70	10		0.59000		
V50	10		0.59600	0.59600	
V30	10			0.60200	
V0	10				0.64600
Sig.		1.000	0.523	0.523	1.000

Table A8. Thickness in Tukey Table for 30g/m^2

	N	Subset for alpha = 0.05	
fibers	1	2	1
V100	10	0.43000	
V70	10	0.43200	
V50	10	0.43600	
V30	10	0.45000	0.45000
V0	10		0.46400

3. Fibers effects on Tensile Strength MD through Tukey table

Table A9. Tensile Strength MD in Tukey Table for 100% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	38.33333		
50sqm	6		85.00000	
80sqm	6			122.00000
Sig.		1.000	1.000	1.000

Table A10. Tensile Strength MD in Tukey Table for 30% PES-70% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	44.66667		
50sqm	6		91.00000	
80sqm	6			156.00000
Sig.		1.000	1.000	1.000

Table A11. Tensile Strength MD in Tukey Table for 50% PES-50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	45.33333		
50sqm	6		94.33333	
80sqm	6			157.00000
Sig.		1.000	1.000	1.000

Table A12. Tensile Strength MD in Tukey Table for 70% PES-30% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	46.00000		
50sqm	6		96.66667	
80sqm	6			173.66667
Sig.		1.000	1.000	1.000

Table A13. Tensile Strength MD in Tukey Table for 100% PES

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	66.00000		
50sqm	6		153.00000	
80sqm	6			253.33333
Sig.		1.000	1.000	1.000

4. Weight Effects on Tensile Strength MD in Tukey Table

Table A13. Tensile Strength MD in Tukey Table for 30sqm

	N	Subset for alpha = 0.05	
fibers	1	2	1
V100	10	0.43000	
V70	10	0.43200	
V50	10	0.43600	
V30	10	0.45000	0.45000
V0	10		0.46400
Sig.		0.079	0.357

Table A14. Tensile Strength MD in Tukey Table for 30sqm

	N	Subset for alpha = 0.05		
fibers	1	2	3	1
V100	6	38.33333		
V70	6		44.66667	
V50	6		45.33333	
V30	6		46.00000	
V0	6			66.00000
Sig.		1.000	0.248	1.000

Table A15.Tensile Strength MD in Tukey Table for 50sqm

	N	Subset for alpha = 0.05				
fibers	1	2	3	4	5	1
V100	6	85.00000				
V70	6		91.00000			
V50	6			94.33333		
V30	6				96.66667	
V0	6					153.00000
Sig.		1.000	1.000	1.000	1.000	1.000

Table A16Tensile Strength MD in Tukey Table for 80sqm

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	6	122.00000			
V70	6		156.00000		
V50	6		157.00000		
V30	6			173.66667	
V0	6				253.33333
Sig.		1.000	0.696	1.000	1.000

5 Fibers Effects On Tensile Strength CD In Tukey Table

Table A17. Tensile Strength CD in Tukey Table for 100% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	9.66667		
50sqm	6		21.00000	
80sqm	6			31.33333
Sig.		1.000	1.000	1.000

Table A18. Tensile Strength CD in Tukey Table for 30% PES-70% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	10.66667		
50sqm	6		21.33333	
80sqm	6			32.33333

Table A19. Tensile Strength CD in Tukey Table for 50% PES-50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	12.00000		
50sqm	6		22.66667	
80sqm	6			34.66667
Sig.		1.000	1.000	1.000

Table A20. Tensile Strength CD in Tukey Table for 50% PES-50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	12.33333		
50sqm	6		25.00000	
80sqm	6			38.50000
Sig.		1.000	1.000	1.000

Table A21. Tensile Strength CD in Tukey Table for 100% PES

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	13.66667		
50sqm	6		39.00000	
80sqm	6			64.00000
Sig.		1.000	1.000	1.000

6. Weight Effects on Tensile Strength CD in Tukey Table

Table A22. Tensile Strength CD in Tukey Table for 30sqm

	N	Subset for alpha = 0.05		
fibers	1	2	3	1
V100	6	9.66667		
V70	6	10.66667		
V50	6		12.00000	
V30	6		12.33333	
V0	6			13.66667
Sig.		0.062	0.876	1.000

Table A23. Tensile Strength CD in Tukey Table for 50sqm

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	6	21.00000			
V70	6	21.33333			
V50	6		22.66667		
V30	6			25.00000	
V0	6				39.00000
Sig.		0.900	1.000	1.000	1.000

Table A24. Tensile Strength CD in Tukey Table for 80sqm

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	6	31.33333			
V70	6	32.33333			
V50	6		34.66667		
V30	6			38.50000	
V0	6				64.00000
Sig.		0.313	1.000	1.000	1.000

7. Fiber Effects on Elongation at Break CD in Tukey Table

Table A25. Elongation at Break CD in Tukey Table in Tukey Table for 100% PE

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	30.00000		
50sqm	6		32.00000	
80sqm	6			35.00000
Sig.		1.000	1.000	1.000

Table A26. Elongation at Break CD in Tukey Table for 30% PES-70% CV

	N	Subset for alpha = 0.05	
weight	1	2	1
30sqm	6	33.16667	
50sqm	6	35.00000	
80sqm	6		40.00000
Sig.		0.052	1.000

Table A27. Elongation at Break CD in Tukey Table for 50% PES-50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	40.00000		
50sqm	6		42.00000	
80sqm	6			45.00000
Sig.		1.000	1.000	1.000

Table A28. Elongation at Break CD in In Tukey Table for 70% PES-30% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	45.00000		
50sqm	6		47.00000	
80sqm	6			50.00000
Sig.		1.000	1.000	1.000

Table A29. Elongation at Break CD in Tukey Table for 100% PES-

	N	Subset for alpha = 0.05	
weight	1	2	1
30sqm	6	50.00000	
50sqm	6	51.00000	
80sqm	6		55.00000
Sig.		0.284	1.000

8. Weight effects on Elongation at Break CD in Tukey table

Table A30. Elongation at Break CD in for 30sqm

	N	Subset for alpha = 0.05				
fibers	1	2	3	4	5	1
V100	6	30.00000				
V70	6		33.16667			
V50	6			40.00000		
V30	6				45.00000	
V0	6					50.00000
Sig.		1.000	1.000	1.000	1.000	1.000

Table A31. Elongation at Break CD in Tukey Table for 50sqm

	N	Subset for alpha = 0.05				
fibers	1	2	3	4	5	1
V100	6	32.00000				
V70	6		35.00000			
V50	6			42.00000		
V30	6				47.00000	
V0	6					51.00000
Sig.		1.000	1.000	1.000	1.000	1.000

Table A32. Elongation at Break CD in Tukey Table for 80sqm

	N	Subset for alpha = 0.05				
fibers	1	2	3	4	5	1
V100	6	35.00000				
V70	6		40.00000			
V50	6			45.00000		
V30	6				50.00000	
V0	6					55.00000
Sig.		1.000	1.000	1.000	1.000	1.000

9. Blend fiber Effects On Elongation at Break MD In Tukey Table

Table A33. Elongation at Break MD in Tukey Table in Tukey Table for 100% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	140.00000		
50sqm	6		145.00000	
80sqm	6			153.00000
Sig.		1.000	1.000	1.000

Table A34. Elongation at Break MD in Tukey Table for 30%pes 70% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	145.00000		
50sqm	6		150.33333	
80sqm	6			158.00000
Sig.		1.000	1.000	1.000

Table A35. Elongation at Break MD in Tukey Table for 50%pes 50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	150.33333		
50sqm	6		155.66667	
80sqm	6			160.00000
Sig.		1.000	1.000	1.000

Table A36. Elongation at Break MD in Tukey Table for 70%pes 30% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	155.00000		
50sqm	6		160.00000	
80sqm	6			165.00000
Sig.		1.000	1.000	1.000

Table A37 Elongation at Break MD in Tukey Table for 100%pes

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	165.00000		
50sqm	6		170.00000	
80sqm	6			175.00000
Sig.		1.000	1.000	1.000

10. Weight Effects on Elongation at Break MD in Tukey Table

Table A38. Elongation at Break MD in Tukey Table for 30sqm

	N	Subset for alpha = 0.05				
fibers	1	2	3	4	5	1
V100	6	140.00000				
V70	6		145.00000			
V50	6			150.33333		
V30	6				155.00000	
V0	6					165.00000
Sig.		1.000	1.000	1.000	1.000	1.000

Table A39. Elongation at Break MD in Tukey Table for 50sqm

	N	Subset for alpha = 0.05				
fibers	1	2	3	4	5	1
V100	6	145.00000				
V70	6		150.33333			
V50	6			155.66667		
V30	6				160.00000	
V0	6					170.00000
Sig.		1.000	1.000	1.000	1.000	1.000

Table A40. Elongation at Break MD in Tukey Table for 80sqm

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	6	153.00000			
V70	6		158.00000		
V50	6		160.00000		
V30	6			165.00000	
V0	6				175.00000
Sig.		1.000	0.200	1.000	1.000

11. Blend fiber effects on Tear Resistance CD through in table

Table A41. Tear Resistance CD in Tukey Table for 100% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	8.00000		
50sqm	6		9.66667	
80sqm	6			15.00000
Sig.		1.000	1.000	1.000

Table A42. Tear Resistance CD in Tukey Table for 30% pes 70% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	9.33333		
50sqm	6		12.33333	
80sqm	6			22.00000
Sig.		1.000	1.000	1.000

Table A43. Tear Resistance CD in Tukey Table for 50% pes 50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	10.41667		
50sqm	6		15.33333	
80sqm	6			26.00000
Sig.		1.000	1.000	1.000

Table A44. Tear Resistance CD in Tukey Table for 70% pes 30% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	10.66667		
50sqm	6		16.33333	
80sqm	6			31.33333
Sig.		1.000	1.000	1.000

Table A45. Tear Resistance CD in Tukey Table for 100% pes

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	11.33333		
50sqm	6		17.33333	
80sqm	6			44.66667
Sig.		1.000	1.000	1.000

12. Weight Effects on Tear Resistance CD in Tukey Table

Table A46. Tear Resistance CD in Tukey Table for 30sqm

	N	Subset for alpha = 0.05		
fibers	1	2	3	1
V100	6	8.00000		
V70	6	9.33333	9.33333	
V50	6		10.41667	10.41667
V30	6		10.66667	10.66667
V0	6			11.33333
Sig.		0.164	0.164	0.503

Table A47. Tear Resistance CD in Tukey Table for 50sqm

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	6	9.66667			
V70	6		12.33333		
V50	6			15.33333	
V30	6			16.33333	16.33333
V0	6				17.33333
Sig.		1.000	1.000	0.465	0.465

Table A48. Tear Resistance CD in Tukey Table for 80sqm

	N	Subset for alpha = 0.05				
fibers	1	2	3	4	5	1
V100	6	15.00000				
V70	6		22.00000			
V50	6			26.00000		
V30	6				31.33333	
V0	6					44.66667
Sig.		1.000	1.000	1.000	1.000	1.000

13. Blend fiber Effects On Tear Resistance MD in Tukey Table

Table A49. Tear Resistance MD in Tukey Table for 100% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	16.00000		
50sqm	6		38.66667	
80sqm	6			45.00000
Sig.		1.000	1.000	1.000

Table A50. Tear Resistance MD in Tukey Table for 70% PES -30% CV

weight	N	Subset for alpha = 0.05		
	1	2	3	1
30sqm	6	22.00000		
50sqm	6		41.00000	
80sqm	6			78.66667
Sig.		1.000	1.000	1.000

Table A51. Tear Resistance MD in Tukey Table for 50% pes -50% CV

weight	N	Subset for alpha = 0.05		
	1	2	3	1
30sqm	6	24.00000		
50sqm	6		44.66667	
80sqm	6			81.66667
Sig.		1.000	1.000	1.000

Table A52. Tear Resistance MD in Tukey Table for 70% pes -30% CV

weight	N	Subset for alpha = 0.05		
	1	2	3	1
30sqm	6	31.00000		
50sqm	6		51.00000	
80sqm	6			126.33333
Sig.		1.000	1.000	1.000

Table A53. Tear Resistance MD in Tukey Table for 70% pes -30% CV

weight	N	Subset for alpha = 0.05		
	1	2	3	1
30sqm	6	36.66667		
50sqm	6		75.00000	
80sqm	6			175.00000
Sig.		1.000	1.000	1.000

14. Weight Effects on Tear Resistance MD in Tukey Table

Table A54. Tear Resistance MD in Tukey Table for 30sqm

fibers	N	Subset for alpha = 0.05				
	1	2	3	4	5	1
V100	6	16.00000				
V70	6		22.00000			
V50	6			24.00000		
V30	6				31.00000	
V0	6					36.66667
Sig.		1.000	1.000	1.000	1.000	1.000

Table A55. Tear Resistance MD in Tukey Table for 50sqm

fibers	N	Subset for alpha = 0.05				
	1	2	3	4	5	1
V100	6	38.66667				
V70	6		41.00000			
V50	6			44.66667		
V30	6				51.00000	
V0	6					75.00000
Sig.		1.000	1.000	1.000	1.000	1.000

Table A56. Tear Resistance MD in Tukey Table for 80sqm

fibers	N	Subset for alpha = 0.05				
	1	2	3	4	5	1
V100	6	45.00000				
V70	6		78.66667			
V50	6			81.66667		
V30	6				126.33333	
V0	6					175.00000
Sig.		1.000	1.000	1.000	1.000	1.000

15. Blend Fiber Effects on Water Absorbency Capacity in Tukey Table

Table A57. Water Absorbency Capacity in Tukey Table for 100% CV

weight	N	Subset for alpha = 0.05
	1	1
30sqm	6	1190.33333
50sqm	6	1195.00000
80sqm	6	1196.00000
Sig.		0.119

Table A58. Water Absorbency Capacity in Tukey Table for 70 PES -30% CV

weight	N	Subset for alpha = 0.05
	1	1
50sqm	6	1170.00000
80sqm	6	1170.33333
30sqm	6	1175.00000
Sig.		0.217

Table A59. Water Absorbency Capacity in Tukey Table for 50% PES -50% CV

weight	N	Subset for alpha = 0.05
	1	1
50sqm	6	1165.00000
80sqm	6	1165.50000
30sqm	6	1165.66667
Sig.		0.971

Table A60. Water Absorbency Capacity in Tukey Table for 30% PES -70% CV

weight	N	Subset for alpha = 0.05
	1	1
80sqm	6	1157.33333
50sqm	6	1160.00000
30sqm	6	1163.16667
Sig.		0.121

Table A61. Water Absorbency Capacity in Tukey Table for 100% CV

weight	N	Subset for alpha = 0.05	
	1	2	1
30sqm	6	780.00000	
50sqm	6	875.00000	
80sqm	6		900.00000
Sig.		0.627	1.000

16. Weight Effects Water Capacity in Tukey Table

Table A62. Water Absorbency Capacity in Tukey Table for 30sqm

fibers	N	Subset for alpha = 0.05	
	1	2	1
V0	6	780.00000	
V30	6		1163.16667
V50	6		1165.66667
V70	6		1175.00000
V100	6		1190.33333

Table A63. Water Absorbency Capacity in Tukey Table for 50sqm

fibers	N	Subset for alpha = 0.05		
	1	2	3	1
V0	6	875.00		
V30	6		1160.	
V50	6		1165.	
V70	6		1170.	
V100	6			1195.00
Sig.		1.000	0.165	1.000

Table A64. **Water Absorbency Capacity** in Tukey Table for 80sqm

fibers	N	Subset for alpha = 0.05		
	1	2	3	1
V0	6	900.00000		
V30	6		1157.33	
V50	6		1165.50	1165.5
V70	6		1170.33	1170.33
V100	6			1196.0
Sig.		1.000	0.805	0.105

17. Blend Fiber Effects on Water Absorbency Time in Tukey Table

Table A65. Absorbency time in Tukey Table for 100% CV

weight	N	Subset for alpha = 0.05	
	1	2	1
80sqm	6	4.00000	
50sqm	6	4.03333	4.03333
30sqm	6		4.10000
Sig.		0.633	0.187

Table A66. Absorbency time in Tukey Table for 30% PES -70% CV

weight	N	Subset for alpha = 0.05
	1	1
80sqm	6	5.86667
50sqm	6	5.90000
30sqm	6	5.95000
Sig.		0.541

Table A67. Absorbency time in Tukey Table for 50% PES -50% CV

weight	N	Subset for alpha = 0.05
	1	1
80sqm	6	6.10000
50sqm	6	6.21667
30sqm	6	6.23333
Sig.		0.148

Table A68. Absorbency time in Tukey Table for 70% pes -30% CV

weight	N	Subset for alpha = 0.05
	1	1
50sqm	6	6.24167
80sqm	6	6.25000
30sqm	6	6.30000
Sig.		0.646

Table A69. Absorbency time in Tukey Table for 100% pes

weight	N	Subset for alpha = 0.05	
	1	2	1
80sqm	6	9.80000	
50sqm	6		10.16667
30sqm	6		10.26667
Sig.		1.000	0.541

18. Weight Effects on Water Absorbency Time In Tukey Table

Table A70. Absorbency time in Tukey Table for 30sqm

fibers	N	Subset for alpha = 0.05			
	1	2	3	4	1
V100	6	4.10000			
V70	6		5.95000		
V50	6			6.23333	
V30	6			6.30000	
V0	6				10.26667
Sig.		1.000	1.000	0.907	1.000

Table A71. Absorbency time in Tukey Table for 50sqm

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	6	4.03333			
V70	6		5.90000		
V50	6			6.21667	
V30	6			6.24167	
V0	6				10.16667
Sig.		1.000	1.000	0.995	1.000

Table A72. Absorbency time in Tukey Table for 80sqm

	N	Subset for alpha = 0.05			
fibers	1	2	3	4	1
V100	6	4.00000			
V70	6		5.86667		
V50	6			6.10000	
V30	6			6.25000	
V0	6				9.80000
Sig.		1.000	1.000	0.189	1.000

19. Blend Fiber Effects on Whiteness in Tukey Table

Table A73. Whiteness in Tukey Table for 100% pes

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	72.440000		
50sqm	6		76.020000	
80sqm	6			77.250000
Sig.		1.000	1.000	1.000

Table A74. Whiteness in Tukey Table for 30% PES 70% CV

weight	N	Subset for alpha = 0.05		
	1	2	3	1
30sqm	6	72.960000		
50sqm	6		76.320000	
80sqm	6			77.330000
Sig.		1.000	1.000	1.000

Table A75. Whiteness in Tukey Table for 50% pes 50% CV

	N	Subset for alpha = 0.05		
weight	1	2	3	1
30sqm	6	73.580000		
50sqm	6		76.440000	
80sqm	6			77.480000
Sig.		1.000	1.000	1.000

Table A76. Whiteness in Tukey Table for 70% pes 30% CV

weight	N	Subset for alpha = 0.05		
	1	2	3	1
30sqm	6	73.870000		
50sqm	6		76.550000	
80sqm	6			77.610000
Sig.		1.000	1.000	1.000

Table A77. Whiteness in Tukey Table for 100% pes

weight	N	Subset for alpha = 0.05		
	1	2	3	1
30sqm	6	73.93		
50sqm	6		77.65	
80sqm	6			78.61
Sig.		1.000	1.000	1.00

20. Weight Effects on Whiteness In Tukey Table

Table A78. Whiteness in Tukey Table for 30sqm

fibers	N	Subset for alpha = 0.05				
	1	2	3	4	5	1
V100	6	72.44				
V70	6		72.96			
V50	6			73.58		
V30	6				73.87	
V0	6					73.93
Sig.		1.000	1.000	1.000	1.000	1.00

Table A79. Whiteness in Tukey Table for 50sqm

fibers	N	Subset for alpha = 0.05				
	1	2	3	4	5	1
V100	6	76.02				
V70	6		76.32			
V50	6			76.44		
V30	6				76.55000	
V0	6					77.65
Sig.		1.00	1.0	1.000	1.000	1.000

Table A80. Whiteness in Tukey Table for 80sqm

fibers	N	Subset for alpha = 0.05				
	1	2	3	4	5	1
V100	6	77.25000				
V70	6		77.33000			
V50	6			77.48000		
V30	6				77.61000	
V0	6					78.61000
Sig.		1.000	1.000	1.000	1.000	1.000

2. CORELATION ANALYSES

Table A81 Result of Correlation Analyses

Correlations

	TH	TMD	TCD	EMD	ECD	TRMD	TRCD	ACap	ATime	WH
TH	1									
TMD	0.942(**)	1								
TCD	0.914(**)	0.986(**)	1							
EMD	0.451(**)	0.606(**)	0.610(**)	1						
ECD	0.629(**)	0.761(**)	0.762(**)	0.935(**)	1					
TRMD	0.849(**)	0.955(**)	0.943(**)	0.686(**)	0.777(**)	1				
TRCD	0.846(**)	0.938(**)	0.923(**)	0.663(**)	0.742(**)	.0.981(**)	1			
ACap	-0.134	-0.33 (**)	-0.35(**)	-0.601(**)	-0.640(**)	-0.349(**)	-0.285(**)	1		
ATime	0.220(*)	0.468(**)	0.488(**)	0.835(**)	0.835(**)	0.522(**)	0.474(**)	0.816(**)	1	
WH	0.949(**)	0.895(**)	0.883(**)	0.491(**)	0.663(**)	0.770(**)	0.745(**)	-0.176	0.289(**)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
TH: Thickness TMD: Tensile Md, TCD: Tensile Cd, EMD: Elongation At Break, Md, ECD: Elongation At Break CD, TRMD: Tear Resistance Md, TRC: Tear Resistance Cd, Acap: Absorbency Cap, Atime: Absorbency Time WH: Whiteness

3. REGRESSION ANALYZES

3.1. Dependent Variable: Thickness

Table A82 Thickness variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)		Enter

a All requested variables entered.

Table A83 Thickness model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.984(a)	0.969	0.968	0.02362

Table A84. ANOVA Table for thickness

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.512	2	0.756	1354.971	0.000(a)
	Residual	0.049	87	0.001		
	Total	1.561	89			

a Predictors: (Constant), fibers, weight

b Dependent Variable: thickness

Table A85. Coefficients table for thickness

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	0.306	0.008		39.023	0.000
	weight	0.006	0.000	0.967	51.126	0.000
	fibers	-0.001	0.000	-0.185	-9.800	0.000

a Dependent Variable: thickness

3.2. Dependent Variable: Tensile Strength MD

Table A86 Tensile Strength MD variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

b Dependent Variable: TensileMD

Table A87 Tensile Strength model summary in MD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.949(a)	0.900	0.898	18.93445

a Predictors: (Constant), fibers, weight

Table A88. ANOVA Table for tensile Strength in MD

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	280267.15	2	140133.578	390.874	0.000(a)
	Residual	31190.667	87	358.513		
	Total	311457.82	89			

a Predictors: (Constant), fibers, weight

Table A89. Coefficients table for tensile strength in MD

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	10.436	6.277		1.663	0.100
	weight	2.470	.097	0.863	25.433	0.000
	fibers	-0.681	.059	-0.394	-11.615	0.000

a Dependent Variable: TensileMD

3.3. Dependent Variable: Tensile Strength CD

Table A90 Tensile Strength CD variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

b Dependent Variable: TensileCD

Table A91 Tensile Strength model summary in CD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.913(a)	0.833	0.829	5.89666

a Predictors: (Constant), fibers, weight

Table A92. ANOVA Table for tensile Strength in CD

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15064.616	2	7532.308	216.629	0.000(a)
	Residual	3025.040	87	34.771		
	Total	18089.656	89			

a Predictors: (Constant), fibers, weight

b Dependent Variable: TensileCD

Table A93. Coefficients table for tensile strength in CD

Model		Un standardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	4.377	1.955		2.239	0.028
	weight	0.563	0.030	0.816	18.606	0.000
	fibers	-0.170	0.018	-0.409	-9.332	0.000

a Dependent Variable: Tensile CD

3.4. Dependent Variable: Elongation at Break MD

Table A94. Elongation at Break CD variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables enteredb

Table A95. Elongation at Break model summary in MD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.980(a)	0.961	0.960	1.52978

a Predictors: (Constant), fibers, weight

Table A96. ANOVA Table for Elongation at Break in MD

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4981.390	2	2490.695	1064.300	0.000(a)
	Residual	203.599	87	2.340		
	Total	5184.989	89			

a Predictors: (Constant), fibers, weight

Table A97. Coefficients table for Elongation at Break in MD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	46.655	0.507		91.991	0.000
	weight	0.108	0.008	0.293	13.805	0.000
	fibers	-0.208	0.005	-0.935	-44.023	0.000

a Dependent Variable: ElongationMD

3.5. Dependent Variable: Elongation at Break CD

Table A98. Elongation at Break CD variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

Table A99. Elongation at Break model summary in CD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.975(a)	0.950	0.949	2.16929

a Predictors: (Constant), fibers, weight

Table A100. ANOVA Table for Elongation at Break in CD

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7745.084	2	3872.542	822.928	0.000(a)
	Residual	409.405	87	4.706		
	Total	8154.489	89			

a Predictors: (Constant), fibers, weight

Table A101. Coefficients table for Elongation at Break in MD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	156.586	0.719		217.728	0.000
	weight	0.221	0.011	0.477	19.848	0.000
	fibers	-0.238	0.007	-0.850	-35.382	0.000

a Dependent Variable: ElongationCD

3.6. Dependent Variable: Tear Resistance MD

Table A102 Tear Resistance MD variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

b Dependent Variable: TearResistanceMD

Table A103 Tear Resistance MD model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.903(a)	0.815	0.811	18.22744

a Predictors: (Constant), fibers, weight

Table A104. ANOVA Table for Tear Resistance MD

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	127598.050	2	63799.025	192.027	0.000(a)
	Residual	28904.839	87	332.240		
	Total	156502.889	89			

a Predictors: (Constant), fibers, weight

Table A105. Coefficients table for Tear Resistance MD

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	8.538	6.043		1.413	0.161
	weight	1.524	0.094	0.751	16.297	0.000
	fibers	-.0614	0.056	-0.501	-10.884	0.000

a Dependent Variable: TearResistanceMD

3.7. Dependent Variable: Tear Resistance CD

Table A106 Tear Resistance CD variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

b Dependent Variable: TearResistanceCD

Table A107 Tear Resistance model summary in CD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.900(a)	0.810	0.805	4.32440

a Predictors: (Constant), fibers, weight

Table A108. ANOVA Table for Tear Resistance CD

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6918.288	2	3459.144	184.977	0.000(a)
	Residual	1626.937	87	18.700		
	Total	8545.225	89			

a Predictors: (Constant), fibers, weight

b Dependent Variable: TearResistanceCD

Table A109. Coefficients table for Tear Resistance CD

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	4.557	1.434		3.178	0.002
	weight	0.365	0.022	0.769	16.436	0.000
	fibers	-0.134	0.013	0-.467	-9.991	0.000

a Dependent Variable: TearResistanceCD

3.8. Dependent Variable: Absorbency Capacity

Table A110. Absorbency Capacity variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

b Dependent Variable: AbsorbencyCap

Table A111 Absorbency Capacity summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.775(a)	0.600	0.591	92.77397

a Predictors: (Constant), fibers, weight

Table A112. ANOVA Table for Absorbency Capacity

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1124461.139	2	562230.570	65.322	0.000(a)
	Residual	748809.749	87	8607.009		

a Predictors: (Constant), fibers, weight

b Dependent Variable: AbsorbencyCap

Table A113. Coefficients table for Absorbency Capacity

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	921.660	30.757		29.966	0.000
	weight	0.307	0.476	0.044	0.646	0.520
	fibers	3.277	0.287	0.774	11.412	0.000

3.9. Dependent Variable: Absorbency time

Table A114 Absorbency time variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

Table A115 Absorbency time summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.920(a)	0.847	0.843	0.78518

a Predictors: (Constant), fibers, weight

Table A116. ANOVA Table for Absorbency time

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	296.429	2	148.214	240.407	0.000(a)
	Residual	53.637	87	0.617		
	Total	350.065	89			

a Predictors: (Constant), fibers, weight

b Dependent Variable: AbsorbencyTime

Table A117 Coefficients table for Absorbency time

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	9.336	0.260		35.866	0.000
	weight	-0.003	0.004	-0.035	-0.833	0.407
	fibers	-0.053	0.002	-0.920	-21.912	0.000

a Dependent Variable: AbsorbencyTime

3.10. Dependent Variable: Whiteness

Table A118 Whiteness variables

Model	Variables Entered	Variables Removed	Method
1	fibers, weight(a)	.	Enter

a All requested variables entered.

b Dependent Variable: Whiteness

Table A119 Whiteness summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.920(a)	0.847	0.844	0.75850

a Predictors: (Constant), fibers, weight

Table A120. ANOVA Table for Whiteness

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	277.480	2	138.740	241.149	0.000(a)
	Residual	50.053	87	0.575		
	Total	327.533	89			

a Predictors: (Constant), fibers, weight

b Dependent Variable: Whiteness

Table A121. Coefficients table for Whiteness

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	72.221	0.251		287.201	0.000
	weight	0.082	0.004	0.883	21.074	0.000
	fibers	-0.015	0.002	-0.259	-6.179	0.000

a Dependent Variable: Whiteness