Sudan University of Science and Technology

The Graduate College

Development of Novel Nanodiamond Composites for Textile Coating

تطوير ابداعى لمركبات النانودايموند لطلاء النسيج

A thesis Submitted for the fulfillments of the degree of doctor

of philosophy in Textile Engineering

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استهلال

قال تعالى :

وَاللَّهُ جَعَلَ لَكُمْ مِمَّا خَلَقَ ظِلَالًا وَجَعَلَ لَكُمْ مِنَ الْجِبَالِ أَكْنَانًا وَجَعَلَ لَكُمْ سَرَابِيلَ تَقِيكُمُ الْحَرَّ وَسَرَابِيلَ تَقِيكُمْ بَأْسَكُمْ كَذَلِكَ يُتِمُّ نِعْمَتَهُ عَلَيْكُمْ لَعَلَّكُمْ تُسْلِمُونَ

صدق الله العظيم

سورة النحل الاية (81)

DEDICATION

This thesis is dedicated

To

The loving memory of my mother and father,

my dear husband Siddig Awad,

my family, specially my sisters Amel and Manal,

and my daughters Marwa, Malaz ,Noon and Amna.

ACKNOWEDGMENTS

ABSTRACT

This thesis dealt with suitable fabrics to protect human skin from ultraviolet rays (UV) using nanomaterial. Nanomaterials have attracted much of attentions that due to their unique properties demanded in various applications. Their used in textile finishing for imparting advanced functions for textile fabrics attracted many scientists. In this study, novel nanodiamond composites were developed for textile fabrics coating .The nanodiamond were well dispersed in coating by using ultrsonication.

The nanodiamond coating layer effectively absorbed harmful UV rays. The coating layer improved the properties of the untreated textiles. Nine fabrics were used in this project. A coating layer of nanodiamond with binder and acetone were developed and used for coating the fabrics .The fabrics were exposed to ultrasonication then the samples are removed and squeezed out and dried in air which followed by curing in an oven at 120°c for 5 min .

The mass loading of nanodiamonds and ultrasonication time were varied and optimized. Nanodiamonds played a significant role in UV protection and tensile properties .The ultraviolet protection factor of the treated fabrics was significantly enhanced achieving (300%) increase when compared to untreated fabrics .furthermore ,The mechanical and thermal properties of the treated fabrics were improved .The morphology of untreated and treated fabrics was characterized using scanning electron microscope .

المســتخلص

تناولت هذه الأطروحة الأقمشة المناسبة لحماية الجلد البشري من الأشعة فوق البنفسجية باستخدام المواد النانوية .وقد جذبت المواد النانوية الكثير من الاهتمام نظرا لخصائصها الفريدة التي طالت في مختلف التطبيقات. استخدامها في التشطيب النهائي للمنسوجات لنقل وظائف متقدمة لها جذبت العديد من العلماء. في هذه الدراسة، تم تطوير مركبات نانودياموند جديدة لطلاء اقمشة النسيج. نانودياموند كانت متناثرة بشكل جيد في الطلية باستخدام الموجات فوق الصوتية.

طبقة طلاء نانودياموند تمتص بشكل فعال الأشعة فوق البنفسجية الضارة. طبقة الطلاء تحسن خصائص المنسوجات غير المعالجة. تم استخدام تسعة أقمشة في هذا المشروع .وقد تم تطوير طبقة طلاء من نانودياموند مع الرابط والأسيتون وتستخدم لطلاء الأقمشة. تعرضت الأقمشة إلى الموجات فوق الصوتية ثم تتم إزالة العينات وتقلص وتجفف في الهواء الذي يليه علاج في فرن c° 120 لمدة 5 دقائق.

وقد تم تنوع الاوزان من نانودياموندز مع زمن الموجات فوق الصوتية وكانت متنوعة ومثلى. نانودياموندز لعبت دورا هاما في حماية الأشعة فوق البنفسجية وخصائص الشد. وعامل حماية الأشعة فوق البنفسجية للأقمشة المعالجة تحسنت بشكل ملحوظ تحقيق (300٪) زيادة بالمقارنة مع الأقمشة غير المعالجة. وعلاوة على ذلك، تم تحسين الخصائص الميكانيكية والحرارية للأقمشة المعالجة .وشخصت مورفولوجية الأقمشة غير المعالجة والمعالجة باستخدام تقنية المجهر الإلكتروني الماسح ..

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Introduction and Literature Review

List of abbreviations and nomenclature

EM or EMR Electromagnetic radiation

UV   Ultraviolet

UVA   Ultraviolet (waveband) A

UVB   Ultraviolet (waveband) B

UVC   Ultraviolet (waveband) C

UVR Ultraviolet Radiation

DNA Deoxyribo Nucleic Acid

UPF Ultraviolet Protection Factor

NT Nanotechnology

NNI National Nanotechnology Initiative

TNT Trinitrotoluene

ND Nanodiamond

RDX Hexahydro Trinitro Triazine

DP Degree of Polymerization

ASTM American Society for Testing and Materials

FTIR Fourier Transform Infrared Spectrometer

SEM Scanning Electron Microscopy

B Commercial Binder

B-ND Binder-Nanodiamond Composite

TGA Thermo Gravimetric Analysis

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CHAPTER 1

INTRODUCTION & LITERATURE REVIEW

Chapter (1)

Introduction

1-1 Introduction

Sudan is a country that enjoys sunshine all the year .It lies between latitude 4° and 22° north the equator and longitude 22° and 38° in the tropical region.

Many of the workers work under the sun, such as traffic police officers and gold miners and hawkers are exposed daily to the risks of ultraviolet rays during their daily lives. There are no studies in Sudan seeking protection from the risk of ultraviolet rays.

Large number of patients of cancer caused by UV .There is no study in Sudan to protect against UV radiation by clothes.

Since the beginning of creation the first human demand was clothing. First clothes were of leather and then evolved to meet environmental requirements, but now the clothes which we wear are made of fabrics. Fabrics are made from fibers. Fibers are the basis for all textiles.

Fiber
↓
Spinning
↓
Yarn
↓

Knitted fabric   Woven fabric
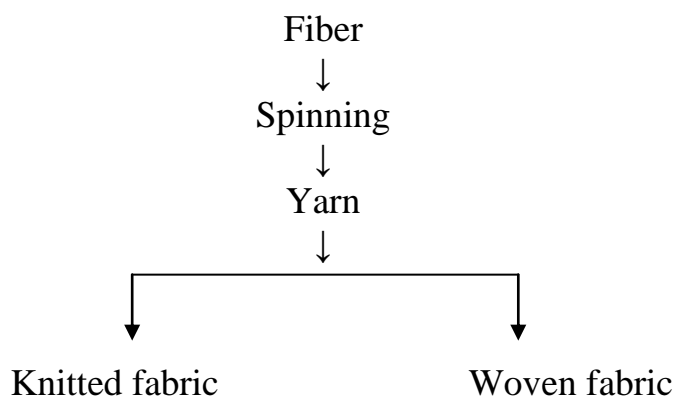
1-2 Sources of Fibres and their Classification

There are many different sources from which we can obtain fibres and therefore, we classify them accordingly (Fig 1-1).

At the start of 20th century suddenly changes occurred and new developments were made in the field of synthetic fibers. Their higher and prompt production   and

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other properties reduced the demand of natural fibers and captured the big market share rapidly.

Textile fibres

- Natural fibre
  - **Plant**
    - **Seed**
      - Cotton
      - Kapok
      - Coir
    - **Bast**
      - Jute
      - Flax
      - Ramie
    - **Leaf**
      - Sisal
      - Pineapple
  - **Animals**
    - Wool
    - Silk
    - Mohair
  - **Mineral**
    - Asbestos
- Man - made fibre
  - **Regenerated Cellulose**
    - Viscose
    - Rayon
  - **Synthetics**
    - Nylon
    - Polyester
    - Acrylic
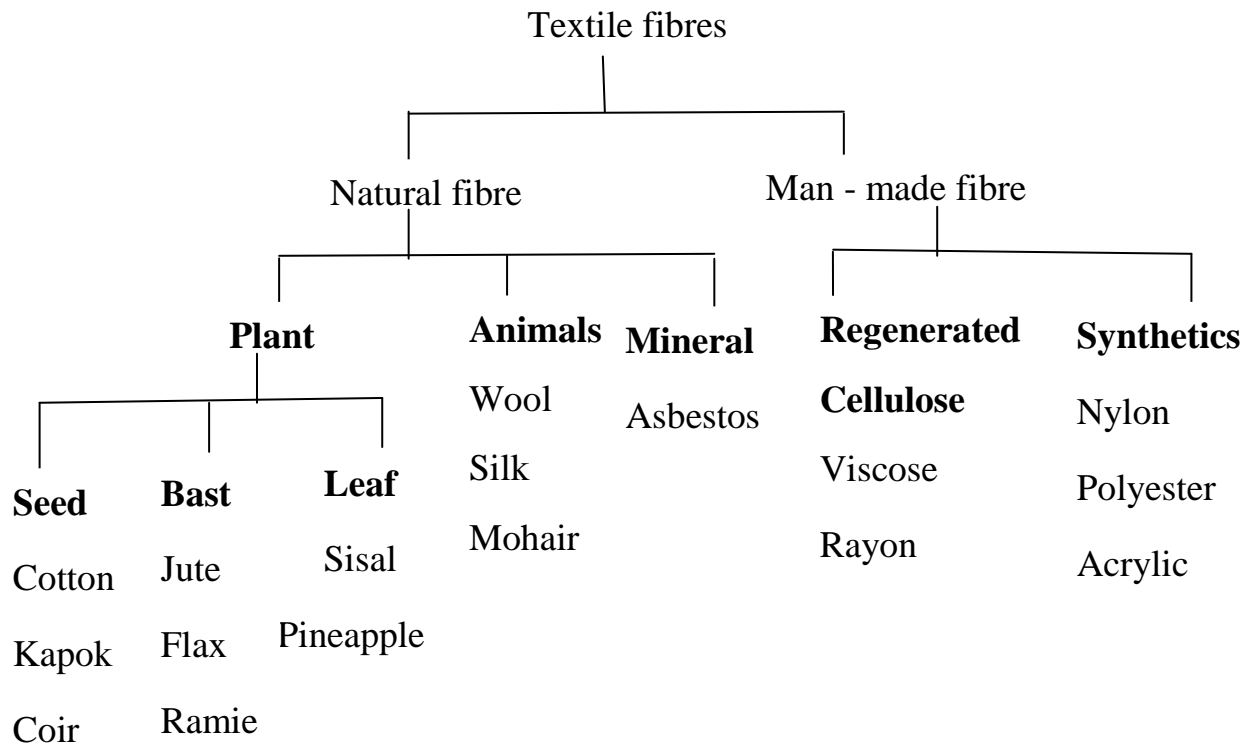
Fig (1-1) classification of fibre

There are various methods of creating fabrics, woven and non woven fabrics. Weaving is the process of interlacing two sets of yarns at right angles. The threads which lie along the length of the fabric are termed warp threads, while those which lie across the width are termed weft threads.

There are three basic weaves; plain weave, twill weave and satin weave. All other weaves are a variation or a combination of these weaves

A plain weave is a weave where each filling passes alternately over and under each warp in a square pattern. The interlacing is opposite in neighboring cells. The repeat is over two ends and two picks.

Clothing is a basic human need. While clothing offers protection, Fabrics are a part of daily life that it is impossible to think about survival without them. Our skin is uncovered and the daily human exposure to UV is dangerous .We can be easily affected by the elements; rain, snow, wind, cold and heat. Clothes play an

important role. They cover our body and protect it from weather changes and adverse climatic conditions.

Reflection is the change in direction of a wave front, at an interface, between two different medias so that the wave front returns into the medium from where it is originated.

1-3 Electromagnetic Radiation

Electromagnetic radiation (EM radiation or EMR) is the radiant energy released by certain electromagnetic processes consisting of electromagnetic waves that synchronized oscillations of electric and magnetic fields that propagate at the speed of light through a vacuum . The oscillations of the two fields are perpendicular to each other and perpendicular to the direction of energy and wave propagation, forming a transverse wave. Electromagnetic waves can be characterized by either the frequency or wavelength of their oscillations.

http://www.chemguide.co.uk/analysis/uvvisible/radiation.html
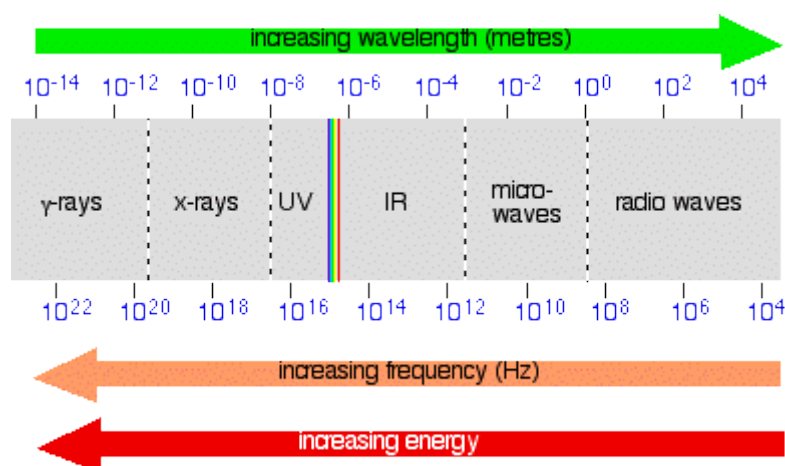
Fig (1-2) electromagnetic radiation

1-3-1 Ultraviolet Rays

Ultraviolet radiation (UV) is an electromagnetic radiation that means "beyond violet" (from Latin ultra, "beyond"). UV light has a shorter wavelength than violet light. Nine percentage of the energy of the sun is in the form of ultraviolet rays. UV radiation has both positive and negative health effects on human beings. These

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UV rays are invisible to humans, but visible to a number of insects as bumblebees and birds.

The electromagnetic spectrum of ultraviolet radiation (UVR) is defined most broadly as 100–400 nanometers and can be subdivided into a number of ranges recommended by the ISO standard ISO-21348.

The scholars divided the regions of ultraviolet radiation into three zones A, B, and C

Ultraviolet A	315-400
Ultraviolet B	280-315
Ultraviolet C	100-280

As frequency increases in the ultraviolet rays the photons can carry enough energy to excite certain double bonded molecules into permanent chemical rearrangement. The DNA is indirectly damaged by reactive oxygen species produced by ultraviolet A (UVA) which has too low energy to damage DNA directly. This is why ultraviolet rays at all wavelengths can damage DNA and is capable of causing skin cancer, burns (sunburn) that are far worse than would be produced by simple heating (temperature increase) effects. This property of causing molecular damage which is out of proportion to heating effects is a characteristic of all EMR with frequencies at the visible light range and above. These properties of high-frequency EMR are due to quantum effects that permanently damage materials and tissues at the molecular level.

UV-B is the most harmful rays and high exposure to it leads to a change in the genetic code, sunburn, changes in tanning, aging of the skin, skin cancer, sunspots, damage to parts of the eye and degradation of the body's immunity. The weakness of the immune system leads to Aids.

High exposure to this radiation can also lead to declination in fish stock, lack of agricultural crops, changes in climate.

1-3-2 Ozone Depletion

The sun transmits rays of all electromagnetic spectrum, but that radiation does not all reach the earth because the atmosphere reflects a large part of this radiation and allows the passage of small part of this ray to pass.

The atmosphere consists mainly of nitrogen and oxygen (78% nitrogen and 21% oxygen). The main part of the oxygen is in the molecular form O_2, but there is also some atomic oxygen (O) and ozone (O_3).

Ozone is a gas found in the atmosphere consisting of three oxygen atoms (O_3). Ozone is formed in the atmosphere when energetic ultraviolet (UV) radiation dissociates molecules of oxygen, O_2, into separate oxygen atoms. Free oxygen atoms can recombine to form oxygen molecules but if a free oxygen atom collides with an oxygen molecule, it joins up, forming ozone. Ozone molecules can also be decomposed by ultraviolet radiation into a free atom and an oxygen molecule. Ozone is thus continuously created and destroyed in the atmosphere by UV radiation coming from the sun. This highly energetic UV radiation is called UVC (wavelength 280 nm) and is very harmful for human health. UVC is fully absorbed in the atmosphere by oxygen and ozone molecules. Ozone also absorbs UVB radiation, which is less energetic (wavelength 280 - 325 nm) but also harmful, before it reaches the surface of the Earth. In this creation/destruction process the amounts of ozone molecules created and destroyed are roughly equal, so that the total amount of ozone in the atmosphere is nearly constant. Therefore some of ultraviolet rays penetrate the atmosphere and reach the earth.
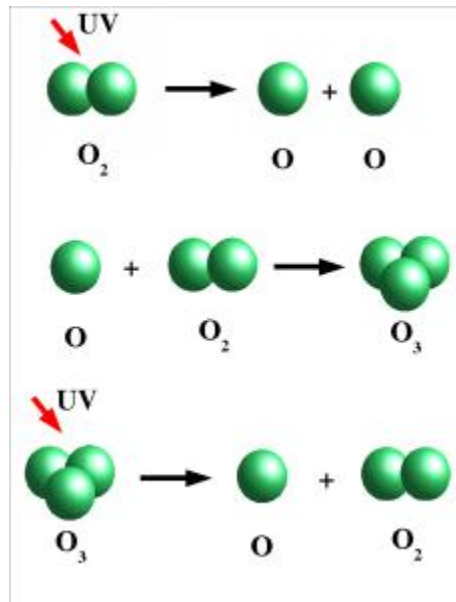
Fig (1-3) formation the ozone

More than 95% of mid-range ultraviolet rays are blocked by the ozone layer and would cause much damage to living organisms if it penetrated the atmosphere.

A decrease of 1% in ozone would lead to increase in the solar UVR at the earth's surface and may eventually lead to a 2.3% increase in skin cancer.

1-3-3 UV Sources

The sun is the principal source of UV exposure to mankind .The light from a mercury lamp is predominantly at discrete wavelengths. Other practical UV sources with more continuous emission spectra include xenon arc lamps (commonly used as sunlight simulators), deuterium arc lamps, mercury-xenon arc lamps, metal-halide arc lamps, and tungsten-halogen incandescent lamps.

1-3-4 Criteria for Increased Exposure of UV Radiation

Workplace, nature of work, the length of stay in the sun during the day, play an important role in increasing the risk of ultraviolet radiation in contact with the skin. Failure to wear appropriate sunglasses can increase the risk of these rays on the cornea and retina.

1-4 Interaction between Fabrics and UV

UV radiation is one of the major causes of degradation of textile materials which is due to excitations in some parts of the polymer molecule and a gradual loss of integrity, and depends on the nature of the fibres [Mallik S.K., Arora T& Achwal W.B2003].

The cloth in terms of structure, color and durability, no matter the form of clothes, the fiber, the design methods, but they all share in the function to provide heat balance of the body and to maintain the temperature unchanged. The rating system for fabrics specifies an Ultraviolet Protection Factor (UPF) value, which can be thought of as a time factor for the protection of Caucasian skin compared to exposure without any protection. The Ultraviolet Protection Factor (UPF) rating system measures the UV protection provided by fabric.

$$UPF = \frac{\sum_{290nm}^{400nm} E_\lambda \times S_\lambda \times \Delta_\lambda}{\sum_{290nm}^{400nm} E_\lambda \times S_\lambda \times T_\lambda \times \Delta_\lambda} \qquad \text{............. (1-1)}$$

Where:

E_λ = erythemal spectral effectiveness

S_λ = solar spectral irradiance in $Wm^{-2}nm^{-1}$

T_λ = spectral transmittance of fabric

Δ_λ = the bandwidth in nm

λ = the wavelength in nm

The numerator of equation (1) described the quantity of the UV radiation reached the skin if unprotected and the denominator described the quantity of the UV radiation reached the skin protected by the garment [Vigo TL, Yang CQ 2005].

There are a number of factors that affect the level of protection provided by fabrics and rated UPF fabric. The descending orders of importance are the weave, color, weight, moisture and other chemical factors.

In textiles, UPF is strongly dependent on the chemical structure of the fibres. The nature of the fibres influences the UPF as they vary in UV transparency [Achwal

W.B 2000]. Natural fibres like cotton, silk, and wool have lower degree UVR absorption than synthetic fibres such as PET [Holme I 2003]

Design challenges protective clothing and facilitates to combine comfort, style and protection in the garment. The ability of fabrics to protect against UV radiation can be tested by two major methods.

Woven fabrics are made from different types of yarns. The raw material of yarn or fibre composition is the initial yarn parameter which has an effect on UVR protection. Fibres have different ability to absorb UV radiation and prevent it from reaching the skin. There is lack of studies dealing with the effect of fibre composition on UV protection.

Using different designs of woven fabrics and various cover factors to see their effects on UV protection.

1-5 Nanotechnology

Nanotechnology (NT) deals with materials from 1 to 100 nm in length. The understanding, manipulation, and control of matter at the physical, chemical, and biological properties of the materials has developed in all fields, especially in the field of textile engineering, but it is in the elementary stages.

The fast development and changes in life style has attracted people towards a more comfortable and luxurious life. The Nanotechnology plays a very important and vital role. The concept of nanotechnology is not new; it was started over forty years ago, according to the National Nanotechnology Initiative (NNI).

Many applications of nanotechnology in textile industry have been currently added as one of the most benefited sector. The wave of nanotechnology has shown a huge potential in textile and clothing industry which is normally very traditional

Industry has tremendously increased the durability of fabrics, its comfortness, its hygienic properties and reduced its production cost.

1-5-1 Nanodiamonds

Nanodiamonds are diamonds with a size below 1 micrometer. They can be produced by impact events such as an explosion or meteoritic impacts.

Diamond nanoparticles, or nanodiamonds, have the most disparate origins. They are found in crude oil at concentrations up to thousands of parts per million, in meteorites, interstellar dust and protoplanetary nebulae, as well as in certain sediment layers on Earth. They can also be produced in the laboratory by chemical vapor deposition or by detonating high explosive materials [Sheemah Kazi 2014].

A (ND) can be created by detonating mixture of trinitrotoluene (TNT) ($C_6H_5N_3O_6$) and hexogen (RDX) ($C_6H_6N_6O_6$) and then gathering the remaining soot.
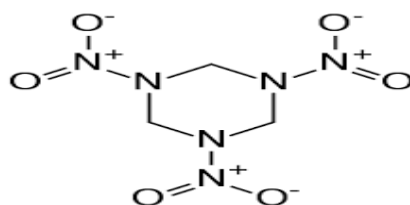
Hexogen
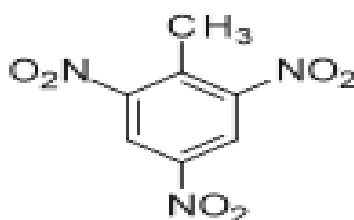
trinitrtoluene

Nanodiamond powder is one of the most promising carbon nano materials to be used in these applications. Attention must be paid to its purity, surface chemistry, dispersion quality, as well as to temperature, ionic composition and other parameters impacting the environment.

The nanodiamond has many unique physical characteristics just like the full karat diamond stone.

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Nanodiamonds have a rounded shape, an active surface and a diamond-like hardness that can be very useful in a number of applications. In addition, nanodiamonds also have wear resistance, they are resistant to steel corrosion and have the physical characteristics of rubber. Additionally, nanodiamonds also have the same lubricating power that oils have.

It has been seen that the nano world is above all, a place where all of our scientific knowledge and technological innovations meet. All functions of the nano world make up our world and consequently a multidisciplinary approach is required. It brings together domains which are at one point separate and merges the know-how and techniques of each. It could possibly give rise to a new paradigm and alter our relationship with the world.

The industrial production of NDs can give the abundant advantage as well as the cheaper price relative to other carbon nanomaterials for various promising applications in nanotechnology. The ND has been used widely in biological applications because of the biocompatibility feature of ND particles. The harmful effects of UV rays for human skin such as skin aging and sunburn trigger scientists for finding protecting solution of textile against their effects. The wide band gaps of ND particles allow NDs to absorb UV light extensively and transparently in the visible light. Nanomaterials have been attracted strong attentions due to their unique physical and chemical properties. Carbon nanomaterials have a distinctive place in nano science due to their own exceptional mechanical, chemical, thermal and electrical properties.

Nanodiamond particles are another form of carbon materials with promising properties and applications.

The application of nanodiamond in textiles for protection from UV will help in finding ways of protection from the risks of these rays.

A mathematical equation that binds the relationship between ultraviolet radiation and the physical and chemical properties of textile materials are recommended for effective protection.

1-6 Objectives

The objectives of this research are summarized as follows:-

- Using different types of fabrics and measuring the ultraviolet reflection by these fabrics to determine the best of them.
- The effect of fabrics properties on ultraviolet reflection
- The study of the mechanical and chemical properties changes in the reflection abilities.
- Formulating mathematical equations linking the amount of ultraviolet rays and properties of textile.
- Using the suitable fabrics to protect human skin from ultraviolet rays.
- To study the functional effects of nano diamond on UV absorbency properties.

1-7 Assumptions

- There is a relationship between the ultraviolet rays and cracking polymer Links
- There is a negative relationship between the durability of the samples and the time exposed to radiation.
- There is a relationship between UV , the weft materials (cotton, polyester and viscose)and installation histocompatibility
- There is a relationship between the density of the cloth and the protection of the UV.

1-8 The Methodology

- Historical method which involves systematic and objective study for fabrics and UV in order to establish facts about them.
- Experimental method that includes isolating all variables and carryout laboratory investigation which determines the effects of UV on the studied fabrics.
- Action method which implies investigating the effects of UV by carrying out the investigation.

The main difficulty is that, no devices for UV experiments are found in Sudan. The ones which are found were not working and the others are not well calibrated .So a decision was made to do all the experiments in the National Institute of Standards in Cairo, Egypt.

1-9 Literature Review

In 1963, Soviet scientists at the All-Union Research Institute of Technical Physics noticed that nanodiamonds were created by nuclear explosions that used carbon-based trigger explosives [Feinberg, Ashley 2014].

Nanodiamond Products was founded in 2009 with the strategy of developing a portfolio of diamond products that spanned a wide range of industries, from lapping silicon carbide to drilling for oil and gas.

In 2015 Dr. Barnard increased the understanding of the structure and stability of carbon nanostructures and the role that it plays in establishing the properties and the interactions under different conditions [Foresight Institute 2015].

There is a lot of research that dealt with ways of protection from ultraviolet rays using different types of fabrics with different designs and different materials using different techniques, and using different methods but all researches did not use the material Nanodaimond in their works.

It also dealt with the different ways to protect people who spend their working hours in outdoors and counseling for those on preventive measures of exposure to excessive ultraviolet [Protection against Exposure to Ultraviolet Radiation] rays.

The work cover lists the following occupations as people at risk in outdoor occupations (Work cover (NSW)) like traffic officers, mining and earth resource workers.

There are a number of documents that outlined the best safety practice of UV exposure reduction [Paolo Vecchia 2007].

Properties of woven fabrics against UV have been studied and the factors effecting, the improvement of UV protection have been evaluated [Dubrovski & Šujica, 1995].

There is a research that indicates that these protective measures can be effective, such as the use of clothing [Osterwalder et al. 2000, Gies et al. 2003& Wilson 2006, 2010].

When UVR strikes on textile surfaces, part of it can be transmitted, absorbed, and reflected by the textiles. Different textile fibres have the tendency to absorb a part of UVR and convert it into different energy forms. Another part of radiation is reflected or scattered by the fibr itself and this may be a part of the transmitted radiation, because another part of UVR transmits directly through the fabric via interstices between fibres and yarns in the fabrics [Alvarez 2003& T. Gambichler2001]

The ultraviolet protection of the textile surfaces change considerably according to the fiber type, the fiber surface smoothness and the fabric cover factor (the fraction of the surface area of the fabric covered by yarns) [Mine AKGUN 2010]

The degree to which a surface absorbs or reflects depends on the medium. For visible radiation, this can have a lot to do with the colour of a surface. The reflection of UV radiation depends more on other factors making up the surface. These factors are the smoothness of the surface, the density, the type of materials and its refractive index.

Natural cotton is more effective than bleached cotton because natural cotton contains UV radiation-absorbing pigments [Morison, 2003]

1-9-1Application of Nano Technology in Textiles

Nanotechnology has been playing an important role in recent textile applications. Some researches work on the application of UV-blocking treatment to fabric using nanotechnology. Inorganic UV blockers are usually certain semiconductor oxides such as TiO_2, ZnO, SiO_2 and Al_2O_3. Among these semiconductor oxides, titanium dioxide (TiO_2) [Gouda, M., Aljaafari,A.I 2012, Wang, X 2010, Periyasamy, S2013] and zinc oxide (ZnO) [Wang, X 2010, Vigneshwaran, N 2006] are

commonly used. It was determined that nano-sized titanium dioxide and zinc oxide were more efficient at absorbing and scattering UV radiation than the conventional size and were better able to block UV [Periyasamy, S2013, Lam, H.L.I.2006].

This is due to the fact that nano-particles have a larger surface area per unit mass and volume than the conventional materials, leading to the increase of the effectiveness of blocking UV radiation. For small particles, light scattering predominates at approximately one-tenth of the wavelength of the scattered light. Rayleigh's scattering theory stated that the scattering was strongly dependent upon the wavelength, where the scattering was inversely proportional to the fourth power wave length. This theory predicts that inorder to scatter UV radiation between 200 and 400 nm, the optimum particle size will be between 20 and 40 nm [Manasi karkare 2008].

UV blocking by surface coating of textiles with nano sized particles of metal oxides has gained more importance recently due to their specific advantages.

UV absorbing inorganic coatings also can be applied by a well established method call sol gel technique.

UV-blocking treatment for cotton fabrics was developed using the sol-gel method. A thin layer of titanium dioxide is formed on the surface of the treated cotton fabric which provides excellent UV-protection [Kong, Y.Y2004, Daoud, W.A2004].

There is limited number of published papers in the field of nanotechnology. There is no a single research used a nanodimond with clothing to protect against UV ray.

CHAPTER 2

MATERIALS AND METHODS

Chapter (2)

Materials and Methods

This chapter presents the materials and methods used in this project. The fabrics and chemicals used are presented before an outline of the preparation of dispersions.

2-1 Materials

Nine fabrics were used in this project; some tests are conducted before exposing them to UV. Then the same tests, after exposure to UV, are conducted on same fabrics at three intervals. All fabrics are produced in Helwan University in Egypt (textile department); their specifications are given in table (2-1).

Table (2-1): Specific*i*ons of fabrics

Materials	The warp yarns are cotton but weft yarns are of : viscose (Samples 1,2,3) polyester (Samples 4,5,6) and cotton (Samples 7,8,9)
Warp count (Ne)	40/2 Ne for all designs
weft count (Ne, Denier)	Viscose 30/2 Ne Polyester 300/1 Denier Cotton 40/2 Ne
Structure	Plain 2/2 (samples 1,4,7) Twill 2/2 (samples 2,5,8) Sateen 4 (samples 3,6,9)
NO of threads /cm	Warp(36 threads /cm) for all designs used
	Weft (21 threads /cm)

2-1-1 Specifica*t*ions of Fabrics

2-1-1-1 Cotton

The cotton fibre is a seed hair formed by the elongation of a single epidermal cell of the cotton seed. This cell continues its growth in length with only   a fine skin. Cotton is composed of 87 - 90% cellulose containing polymer chains in both amorphous and crystalline forms, 6% of moisture and the remainder fats and impurities. Cotton is a natural fiber harvested from the cotton seeds.   After the cotton fiber is gathered from the plant, it can be spun into thread, and then it can be woven into cloth .Cotton clothing is very nice to wear.
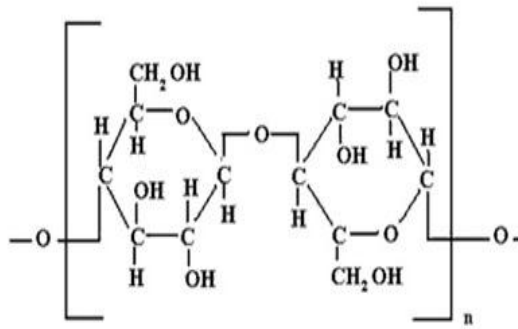
Chemical structure of Cellulose

2-1-1-1-1Natural Cotton Fibre Properties

- Cotton is a soft, absorbent and breathable natural fibre, making it the perfect fibre for clothing and undergarments worn close to the skin
- Cotton keeps the body cool in summer and warm in winter because it is a good conductor of heat
- Cotton is non-allergenic and, unlike synthetic fibres, cotton fibre is a natural product that contains no chemicals
- Cotton, due to its unique fibre structure, breathes better and is more comfortable than oil-based synthetic fabrics

- Cotton is one of the easiest fabrics to dye due to its natural whiteness and high rate of absorbency
- cotton in particular is perfectly suited to colour application processes as it offers spinners crisp white lint, low breakages and stoppages, good throughput efficiency and uniformity of yarn
- Cotton holds up to 27 times its own weight in water and becomes stronger when wet
- Cotton can't hold an electric charge, eliminating static cling

2-1-1-1-2 Physical Properties of Cotton

Physical properties of cotton fibers are given below:

- **Color**

The color of cotton fiber could be white, creamy white, bluish white, yellowish white or grey.

- **Tensile Strength**

Cotton is moderately strong fiber. It has a tenacity of 3-5 gm/den. The strength is greatly affected by moisture, the wet strength of cotton is 20% higher than dry strength.

- **Elongation at break**

Cotton does not stress easily. It has an elongation at break of 5-10%.

- **Elastic Recovery**

Cotton is inelastic and rigid fiber. At 2% extension it has an ER of 74% and at 5% extension it has an ER of 45%.

- **Specific Gravity**

Specific gravity is 1.54.

- **Moisture Regain (MR %)**

Standard moisture regain is 8.5.

- **Effect of Heat**

Cotton has an excellent resistance to degradation by heat. It begins to turn yellow after several hours at 120° C and decomposes marked by at 150° C. As a result of oxidation, cotton is severally damaged after few minutes at 240° C. Cotton burns in air.

- **Effect of Sun Light**

There is a gradual loss of strength when cotton is exposed to sun light and the fiber turn yellow. The degradation of cotton by oxidation is done when heat is promoted and encouraged. By sun light much of the damage is caused by UV-light and by the short waves of visible light.

- **Effect of Age**

Cotton shows a small loss of strength when stored carefully. After 50 years of storage cotton may differ only slightly from the new fibers.

2-1-1-1-3Chemical Properties of Cotton

Cotton is a natural cellulosic fiber and it has some chemical properties:-

- **Effect of Acids**

Cotton is attacked by hot dilute acids or cold concentrated acids which it disintegrates.

- **Effects of Alkalis**

Cotton has an excellent resistance to alkalis. It swells in caustic alkalis (NaOH) but it does not damaged. It can be washed repeatedly in soap solution without any problem.

- **Effect of Organic Solvent**

Cotton has high resistance to normal cleaning solvents. Cotton is dissolved by the copper complexes, such as cup ammonium hydroxide, cupriethylene diamine and concentrated 70% $H_2 SO_4$.

- **Effects of Insects**

Cotton is not attacked by moth-grubs or beetles.

- **Effect of Microorganisms**

Cotton is attacked by fungi and bacteria. Mildews will feed on cotton fabric, rotting and weakling the materials. Mildews and bacteria will flourish on cotton under hot and humid conditions. They can be protected by impregnation with certain types of chemicals. Copper Nepthenateis one of the chemical.

2-1-1-2 Polyester

Polyester is a type of man-made material. It is a synthetic polymer. With 18% market share of all plastic materials produced. It is third after polyethylene (33.5%) and polypropylene (19.5%).Polyester is a category of polymers that contain the ester functional group in their main chain.

Polyester can be spun into yarns, and woven into synthetic fabrics. Polyester is a term often defined as "long-chain polymers chemically composed of at least 85% by weight of an ester and a dihydric alcohol and a terephthalic acid". In other words, it means the linking of several esters within the fibers. Reaction of alcohol with carboxylic acid results in the formation of esters.

Polyester fibers are sometimes spun together with natural fibers to produce a cloth with blended properties.
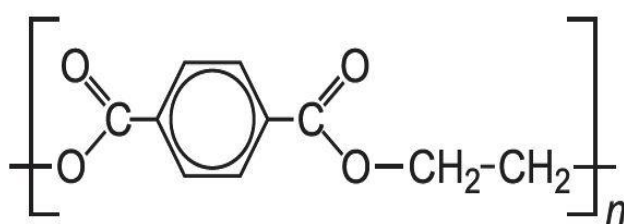
Chemical Formula of Polyester

2-1-1-2-1Physical Properties of Polyester
Polyester fiber consists of some important physical properties. Important physical properties of polyester are given below.

- **Tenacity:** 1. 5 – 7 gm/den
- **Elongation at break**: 15 – 30%

- **Elastic modulus**: 90

- **Elasticity**: Good

- **Moisture Regain (MR%):** 0.40%

- **Specific Gravity**: 1.38

- **Melting point**: 250° C

- **Volumetric Swelling**: None

- **Ability to protest friction**: Excellent

- **Color**: White

- **Light reflection ability**: Good

- **Lusture**: Bright

2-1-1-2-2Chemical Properties of Polyester

Various types of chemical properties of polyester fiber are given below:

- **Acids**

Good resistance to acids in cold condition. But polyester degrades by $H_2 SO_4$ at high temperature.

- **Basic**

Good resistance to basic in cold condition but Strong NaOH dissolves polyester in boiling.

- **Effect of bleaching**

Polyester is not affected by bleaching process.

- **Organic solvents**

Organic solvents have no affect on polyester fiber.

- **Protection ability against mildew**

Good

- **Protection ability against insects**

Good

- **Dyes**

Polyester could be dyed with disperse, azoic color and some pigments.

- **Solvents of polyester**

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Chlorinated hydrocarbon.F_3COOH Phenol (in hot condition)

2-1-1-3 Cotton-Polyester Blends

Poly cotton can be strong, tear-resistant, and low shrinking. Polyester also creates strong environmental resistance compared to plant-derived fibers. Cons of cotton / polyester blends being less breathable than cotton. They trap more moisture while sticking to the skin. They are also less fire resistant [*Mendelson, Cheryl 2005*].

2-1-1-4 Viscose

Viscose rayon is a fiber of regenerated cellulose. It is structurally similar to cotton but may be produced from a variety of plants such as soy, bamboo and sugar cane. Cellulose is a linear polymer of β-D-glucose units with the empirical formula $(C_6H_{10}O_5)_n$ [29]. To prepare viscose, dissolving pulp is treated with aqueous sodium hydroxide (typically 16-19% w/w) to form "alkali cellulose," which has the approximate formula $[C_6H_9O_4\text{-}ONa]_n$. The alkali cellulose is then treated with carbon disulfide to form sodium cellulose xanthate [*Wheeler, Edward 1928*].

Viscose fabric is a soft and lightweight fabric manufactured from a plant-based material called cellulose. Viscose is typically made from woody plants, such as trees and bamboo.

Viscose is part of the rayon family of fabrics, all of which are made from cellulose.
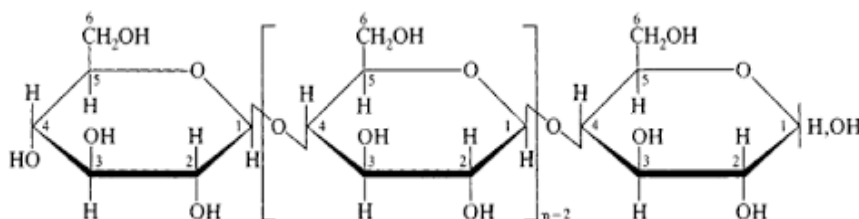
Chemical structure of viscose

2-1-1-4-1 Properties of Viscose

Moisture Absorption

It absorbs more moisture than cotton. Moisture Content of Cotton is 6% at 70 deg F and 65% RH, and for Viscose Rayon it is 13% under the same conditions.

- **Tensile Strength**

  The Tensile Strength of the fibre is less when the fibre is wet than when dry. It is 1.5-2.4 gpd in the dry state and 0.7-1.2 gpd in the wet state. For high tenacity variety the values are 3-4.6 gpd and 1.9 to 3.0 gpd.

- **Elasticity**

  The elasticity of Viscose Rayon is less than 2-3%. This is very important in handling viscose yarns during weaving when sudden tensions are applied.

- **Elongation at Break**

  Ordinary Viscose rayon has 15-30% elongation at break, while high tenacity rayon has only 9-17% elongation at break.

- **Density**

  The density of Viscose rayon is 1.53 g/cc. Rayon filaments are available in three densities: 1.5, 3.0 and 4.5

- **Action of Heat and Light**

  At 300 degree F or more, Viscose Rayon loses its strength and begins to decompose at 350-400 deg F. Prolonged exposure to sunlight also weakens the fibre due to moisture and ultraviolet light of the sunlight.

  2-1-1-4-2 Chemical Properties

  Viscose rayon consists of cellulose of lower DP than cotton cellulose. Also amorphous region of Viscose rayon is present to a greater extent therefore, Viscose rayon reacts faster than cotton with chemicals. Acids like H_2SO_4, HCl breaks the cellulose to hydrocellulose. Oxidising agents

like Na $(OCl)_2$, Bleaching powder, $K_2Cr_2O_7$, $KMnO_4$- form oxycellulose. Cold acid solutions for a short time do not attack viscose rayon.

- **Action of Solvents**

  Textile solvents can be used on Viscose rayon without any deteriorating effect. Viscose rayon dissolves in cup ammonium hydroxide solution

- **Effect of Iron**

  Contact with iron in the form of ferrous hydroxide weakens viscose rayon yarns. Therefore staining, marking or touching of rayon to iron or iron surface should be avoided.

- **Action of Microorganisms**

  Microorganisms (moulds, mildew, fungus, bacteria) affect the colour, strength, dyeing properties and lustre of rayon. Clean and dry viscose rayon is rarely attacked by moulds and mildew.

- **Longitudinal View**

  The longitudinal view of these fibres show many striations running parallel to the long axis of the fibre. The cross section of viscose has striated periphery, having many sharp indentations, and cross sectional contours vary from circular and oval to ribbon-like forms

2-1-1-5 Cotton/Viscose Blend

Blend is unique in many ways and even easy to handle from the wet processing angle. This blended fabric also brings down the production cost by 15 - 20% compared to 100% cotton woven fabric.

2-1-2 Designs of Fabrics Used

2-1-2-1 Plain Weaves

The fabric weave or design is the manner in which the warp and weft threads are interlaced.

The basic starting point of the weave is called a repeat .The first filling is passed over one warp thread and under the next; the second filling goes under the first warp and then passes over the second end.

This design is to produce a ribbed or corded effect .Rib weaves are the derivatives of the plain weave.
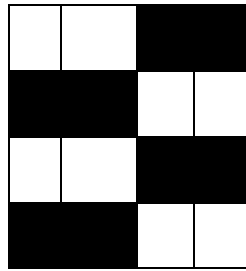
Fig (2-1) plain weave 2/2

2-1-2-2 Sateen

Sateen is a fabric made using a satin weave structure but made with spun yarns instead of filament.
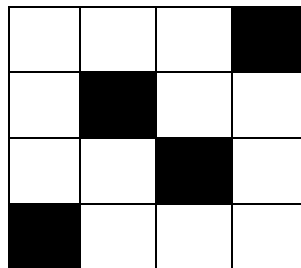
Fig (2-2) sateen 4 weave

The satin weave is characterized by four or more fill or weft yarns floating over a warp yarn or vice versa, four warp yarns floating over a single weft yarn. The sateen weave is characterized by an even and smooth surface of either warp or weft, resulting from a perfectly regular distribution of intersection of those threads. Satin weave is a warp faced whereas sateen weave is weft faced.

2-1-2-3 Twill

Twill is the most durable of all weaves. Twill weave is characterized by diagonal lines running at angles varying between 15°-75°.In this weave the filling yarns are interlaced with the warps in such a way as to form diagonal ridges across the fabric
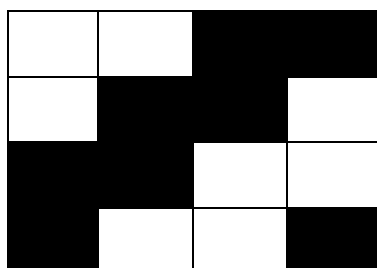
Fig (2-3) twill 2/2

2-2 Methods

2-2-1 Mass per Unit Area (weight) of Fabric

According to the Standard test methods for mass per unit area (Weight) of fabric

(ASTM D3776 / D3776M – 09)

Fig (2-4)

The device (see Fig 2-4) was used in this work to determine the mass per unit area (Weight) of fabric.

The weight of a fabric can be described in two ways, either as the weight per unit area or the weight per unit length.

The method used in this work is weight per unit area. In this test the prescribed nine samples of size 10×10 cm are weighted using highly sensitive balance of three decimals.

The weight of each sample is obtained and the average is calculated. By multiplying the weight by 100, the weight per square meter is obtained.

2-2-2 **Abrasion Resistance of Textile Fabrics**

According to the specification of the standard Guide for Abrasion Resistance of Textile Fabrics (ASTM D3884)
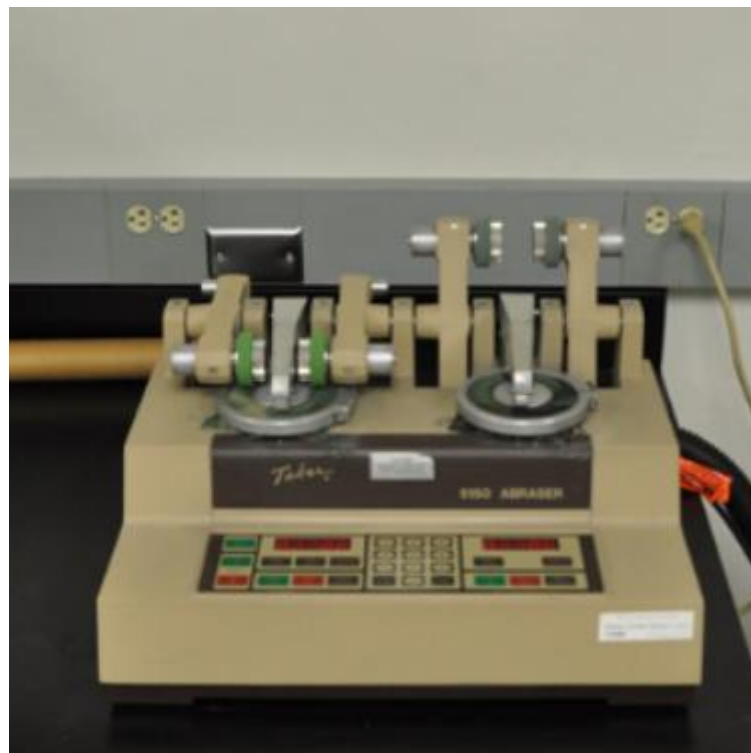
Fig (2-5) Taber Abrasion (Rotary Platform)

The device (see Fig 2-5) was used in this work to determine the standard guide for abrasion resistance of textile fabrics.

A number of important points require consideration before abrasion resistance tests are carried out. Differences will be observed between warp way and weft way abrasion resistance. These differences appear to be associated with the operating conditions of the machine and particularly with the pressure between the abrasion and the sample.

The work of this machine theory is based on a sample of cloth on the device and the other face of the sample facing sandpaper 1500. A number of cycles are run until the sample starts to rupture. Then the device stops and the number of cycles are calculated.

2-2-3 Breaking Force and Elongation of Textile Fabrics (Strip Method)
Determination of the maximum force and elongation at maximum force using the strip method is performed in this work by using the device Tinius olsen
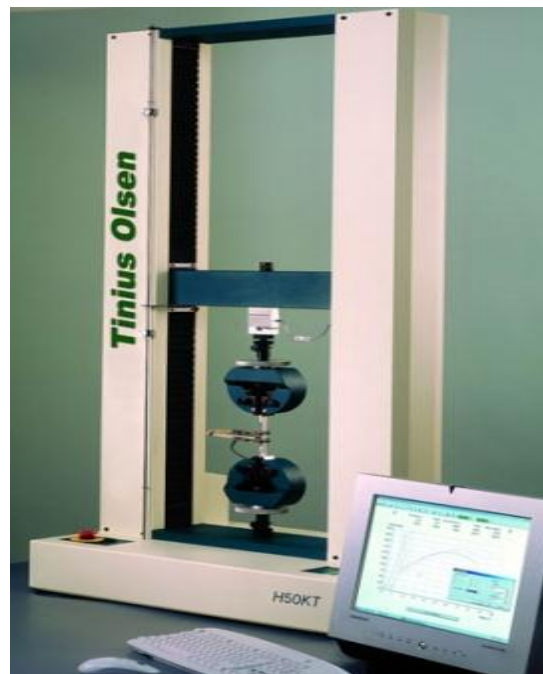
Fig (2-6) Test the RIP is a tensile strength with specification

clear in drawing conclusions from the device

The device (see Fig 2-6) was used in this work to determine the tensile strength and elongation of textile fabrics.

This test method covers raveled strip and cut strip test procedures for determining the breaking force and elongation of most textile fabrics. Provision is made for wet testing. The sample length 20 cm .The machine speed is 100 mm / minute. The tensile strength in both warp and weft directions is done for all samples. The specimen is placed between the jaws of the device at a distance of 20 cm apart. The upper jaw start to move until the sample beaks .The tensile strength and elongation are recorded and drawn on curves.

2-2-4 Standard Test Method for Air Permeability of Textile Fabrics

The device used in this experiment is shown in Fig (2-7). The test is run according to the standard test method for air permeability of Textile Fabrics, (ASTM D 737). The area of sample used is 20 cm^2 .The air pressure used is 125 Pascal .The unit used of the air flow rate through the sample is $cm^3/cm^2/sec$.

Fig (2-7) Air Permeability device

Air space influences a number of important fabric properties such as warmth in protection against rain and wind in clothing and filtration efficiency in industrial cloth.

Applications:

The air permeability of fabrics is the volume of air measured in cubic cm passed per second through one square cm of fabric at a pressure of one cm water. This test method describes the measurement of the air permeability which is the rate of air flow passing perpendicularly through a known area under a prescribed air pressure .It is applicable to most fabrics including woven fabrics, air bag fabrics, blankets, napped fabrics, knitted fabrics, layered fabrics and pile fabrics. It is generally expressed in SI units as $cm^3/s/cm^2$ and in inch-pound units as $ft^3/min/ft^2$.

A circle of fabric is clamped into the tester and the air pressure is made different on one side of the fabric. Airflow pressure will occur higher at one side and lower at the other side of the fabric, from this rate of air flow, the air permeability of the fabric is determined.

2-2-5- Stiffness Tester

Flexible Materials Stiffness Testing

Fig (2-8) - Stiffness tester

The device shown in Fig (2-8) was used in this work to determine the - Stiffness of textile fabrics.

The Taber Fabric Stiffness Tester is simple to use. It is a rugged instrument based on a design described in the international recognized test standards (ASTM D 661). It employs the principle of cantilever bending. A rectangular specimen is supported on a smooth low-friction horizontal platform with a 41. 5" (0.724 rad) or 45" (0,785 rad).There is as adjustable bend angle indicator below the plane of the platform surface. A weighted slide is placed over the specimen and is advanced at a constant rate. As the leading edge of the specimen projects from the Platform, it bends under its own mass. Once the material flexes enough to touch the bend angle indicator, the test is stopped. The length of the overhang is then measured and flexural rigidity and bending modulus can be calculated. To start the test cut a sample of the cloth in the direction of warp length of 18 cm and of a width of 2.5 cm. Place it on the horizontal face. Then push it forward until the parallel region drops down the corner with a line on the side of the device inclination angle of 41.5 degrees. Then calculate the length poison and compensate it in the formula to calculate the stiffness coefficient. Repeat the action in the direction of the weft.

2-2-6 **Ultrviolet Protection Factor (UPF)**

The device shown in Fig (2-9) is used in measuring ultraviolet protection factor. The test is run according to the standards (ASTM 6544-12)

Fig (2-9) Spectrophotometer (UV-VIS)

The significance of this practice is that a cloth, labeled as UV-protective, will be submitted for UV transmittance test in a state that simulates its condition. Therefore; the UV-protection level placed on a label, estimates the maximum UV transmittance of the garment fabric. This practice covers standardized exposures to laundering, simulated sunlight and chlorinated pool water to which cloth, must be exposed prior to testing for UV transmission. This practice leads to measurement of the residual level of UV-protection in fabrics or garments labeled as sun- or UV-protective. The exposure is of about two years of seasonal use. The UV transmission measurements may be done in accordance with ASTM D6544 – 12 using fabrics prepared in accordance with this practice. This measurement may be used in support of a label statement regarding UV protection. The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

2-2-7 Fourier Transform Infrared Spectrometer (FT-IR)
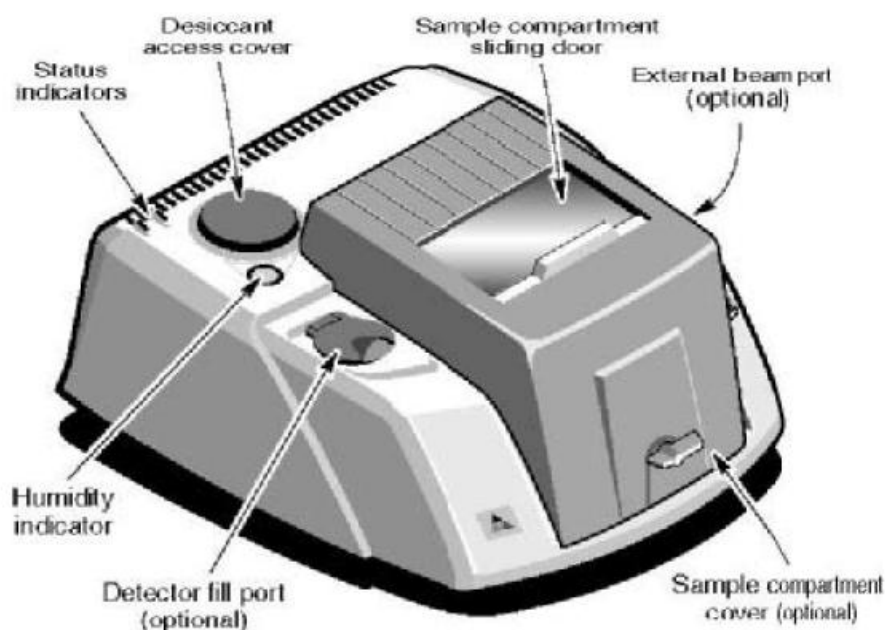
Fig (2-10) Nicolet 380 FT-IR Spectrometer

The method

This test method is relatively quick to perform and is capable of simultaneously detecting multiple parameters, including antioxidants. The size of the peaks is a direct indication of the amount of the specific material found in the sample. The process to analyze the sample is as follows; the first component (1) in the system is the source. The source will emit infrared energy and send it through an aperture to control the amount being presented to the sample. Second, the beam enters the interferometer (2) where it is "encoded" using a series of stationary and movable mirrors. This encoding is a way to produce a signal that consists of all the important infrared frequencies simultaneously. The beam then enters the sample (3) and certain frequencies of the energy are absorbed. The energy that escapes the sample is sent to the detector (4) where it is measured. This measured signal is then sent to a computer (5) where Fourier transformation takes place. Fourier transformation is a mathematical process where a waveform can be broken into an

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alternate representation for easy viewing. Fourier Transform Infrared Spectroscopy (FTIR) [Jeremy,2015] is a technique which is used to obtain an infrared spectrum absorbed or emitted by a solid, liquid or gas. An FTIR spectrometer simultaneously collects high spectral resolution data over a wide spectral range. This confers a significant advantage over a dispersive spectrometer which measures intensity over a narrow range of wavelengths at a time.

FTIR can identify the difference between materials, which are made of same components but have different types of bonds between the elements. The results are typically plotted as a spectrum with frequency on the X-axis and absorption on the Y-axis.

At this point, the results are plotted on the screen, and a simple analysis can be made by the technician.
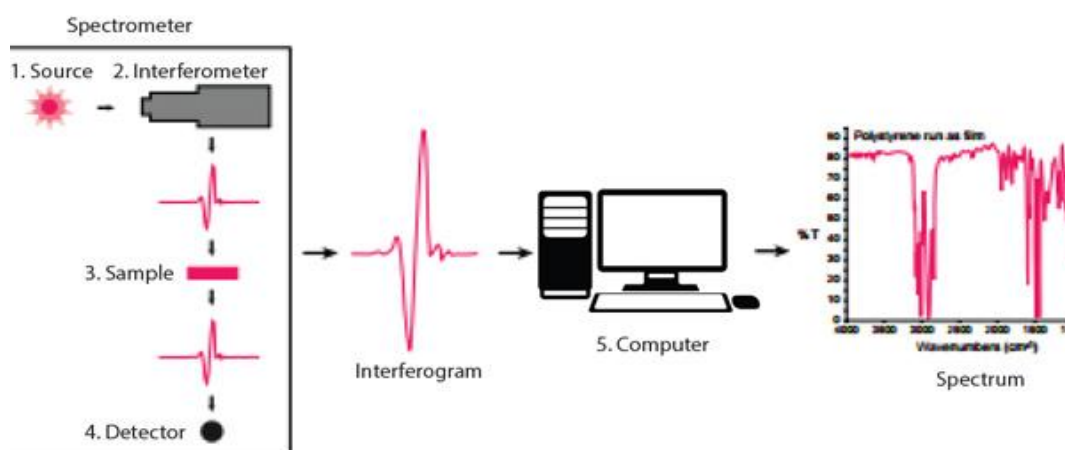
2-2-8 Scanning Electron Microscopy (SEM)

A scanning electron microscope (Quanta FEG-250, with operating at a voltage of 20 kV) is used in this work and shown in figure (2-11).The Quanta FEG-250 SEM instrument is an environmental scanning electron microscope used for high - resolution imaging and composition analysis by energy -dispersive X-ray microanalysis.

Fig (2-11) the Quanta FEG-250 SEM

2-2-9 UV Source

The UV source used in this work is an arc lamp .The irradiance level of the mercury –ARC lamp have been measured using the NIS reference radiometers 268 UVA whose maximum response is located at 365 nm and 268 UVC whose maximum response is located at 254 nm .

The distance between the middle point at surface of the lamb blub and the detector was 20 cm (as requested).

The average reading at UVA is 5.5616 mw/cm^{2}and the average reading at UVC is 3.0782 mw/cm^2

The estimated expanded uncertainty for the above mentioned irradiance value is ±8.05 %(k=2)

Table (2-2) standard /reference /major equipment used for test

Manufacturer	Model	Serial number	Traceability
United detector Technology (UDT)-USA	268 UVA optimized /low profile sensor heads	3B142	NIST-USA
	268 UVC optimized /low profile sensor heads	3B141	

Environmental conditions:-

The conditions at which tests are performed are follows

Humidity: $36 \pm 4\%$c,   The temperature: 28.2 ± 1°

Tests were conducted before and after exposure to uv radiation, and then was treated with chemical nanotechnology.

2-3 Chemicals Materials

2-3-1 Commercial Binder (B)

Binder is an important ingredient as it is used to impart adhesion, gloss and flexibility to the dried film as well as binding particles together. The aim of this work is to synthesize polymeric binders.

Binders have been described by Englelleitner as "an additive to the material being agglomerated that produces bonding strength in the final product.

2-3-2 Acetone

Used in the preparation of coating layer .Acetone is the organic compound with the formula OC $(CH_3)_2$. This colorless, mobile, flammable liquid is the simplest example of the ketones. Acetone is a good solvent for most materials.

2-4 Nano Material

 Nano-materials used in this work have been brought in from China called Nanodiamond. Nanodiamond (ND) of particle size of around 10 nm of 99% purity was obtained from Hongwu International Group LTD, trend Centre, 29-31 Cheung Lee Street Chai Wan, Hong Kong.

2-5 Synthesis Binder-Nanodiamond Composite (B-ND)

In a beaker containing 48 ml of acetone 2 vol% of binder (B) was dissolved. Then variable masses (2, 4, 5, 6 wt. %) of ND based on the final weight of B-ND composite are dispersed. Then the previous dispersion is exposed to ultrasonication (Fig 2-13) at 50 % output for 1, 1.5 and 2 hrs to form B-ND composites Fig (2-12).
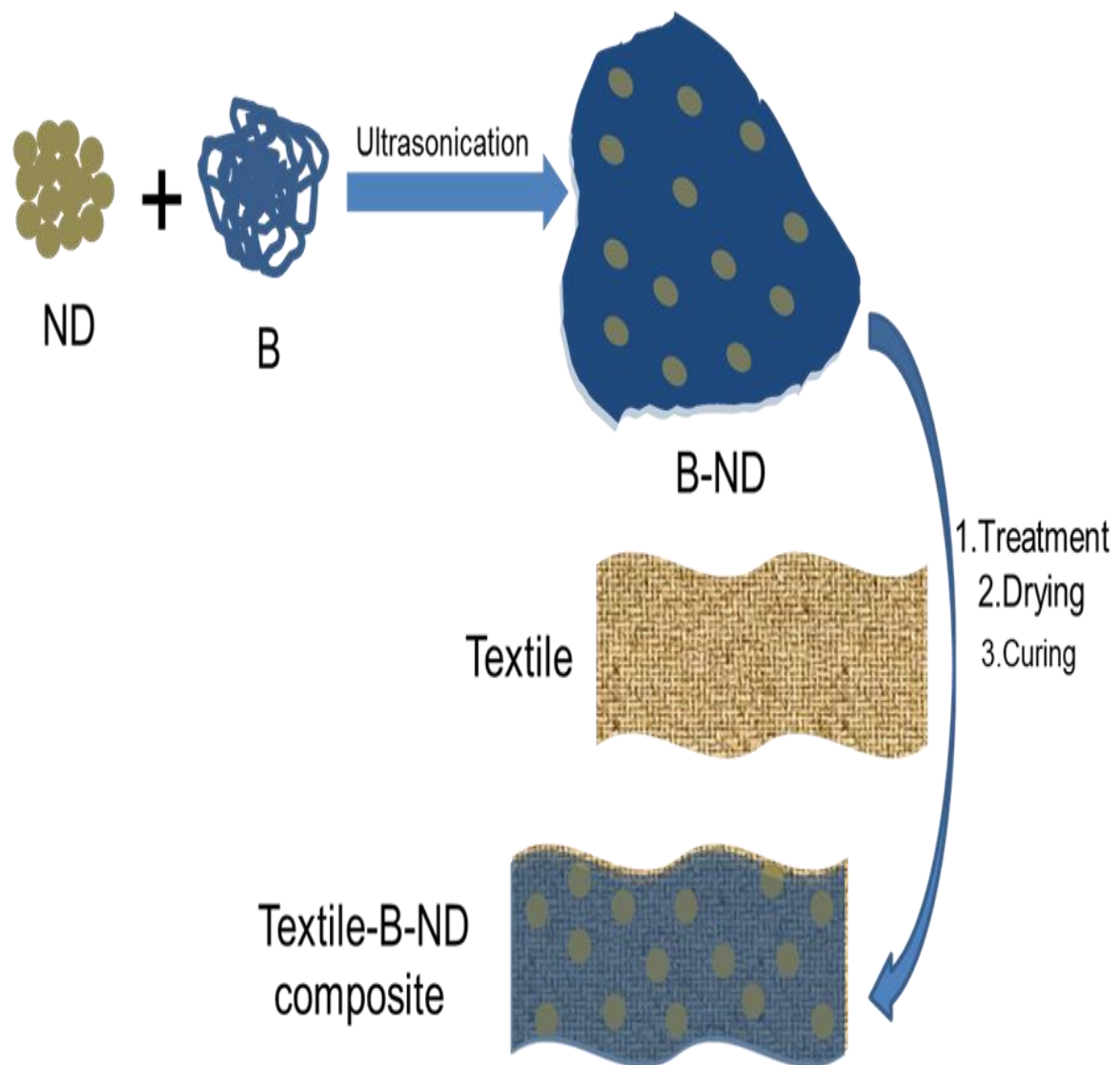
Fig (2-12) Coating process of textiles by ND

2-5-1 Preparation of Textile- B-ND Composites

Different textile samples of 20 cm x 20 cm in dimension were immersed in the different dispersion prepared in three steps for 10 min. Then the sample is removed and squeezed out, and dried in air which followed by curing in oven at 120 $^{\circ}$C for 5 min (see Fig (2-13)).

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultrasonication. Sonication is commonly used in nanotechnology for evenly dispersing nanoparticles in liquids (Ensminger, 1988)

The dispersing and deagglomeration of solids into liquids is an important application of ultrasonic devices. Ultrasonic cavitation generates high shear forces that break particle agglomerates into single dispersed particles. The individual particles are held together by attraction forces of various physical and chemical natures.
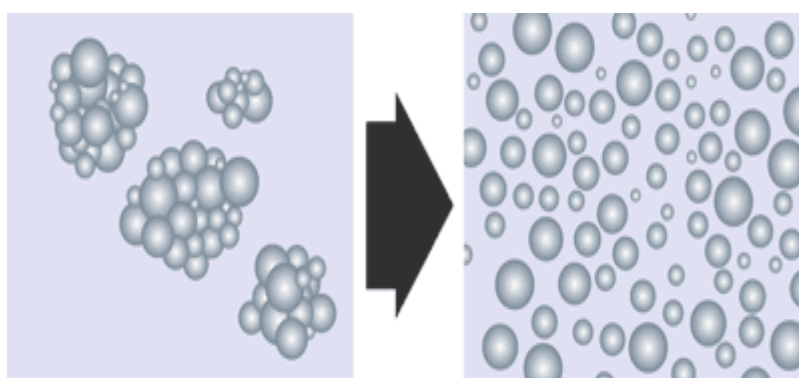
The application of mechanical stress breaks the particle agglomerates apart. Also, liquid is pressed between the particles. Different technologies are commonly used for the dispersing of powders into liquids. This includes high pressure homogenizers, agitator bead mills, impinging jet mills and rotor-stator-mixers. High intensity ultrasonication is an interesting alternative to these technologies.

When sonicating liquids the sound waves that propagate into the liquid media result in alternating high-pressure (compression) and low-pressure (rarefaction) cycles. This applies mechanical stress on the attracting electrostatic forces. Ultrasonic cavitation in liquids causes high speed liquid jets of up to 1000km/h. Such jets press liquid at high pressure between the particles and separate them from each other. Smaller particles are accelerated with the liquid jets and collide at high speeds. This makes ultrasound an effective means for the dispersion and deagglomeration but also for the milling and fine grinding of micron-size and sub micron-size particles.

Fig (2-13) ultrasonication device

2-5-2 Characterization

The SEM images were taken using a scanning electron microscope (Quanta FEG-250, operating at a voltage of 20 kV). UV–Vis spectra were measured using a UV-Vis Spectrophotometer - Shimadzu UV 3101PC in the wavelength range 190-400 nm in transmittance mode. The thermo gravimetric analysis (TGA) was carried out using TGA 50 (TA Shimadzu, Inc.) from room temperature to 750°C. The tensile strength and elongations were tested using tensile testing machine model HI-5KT/S.

CHAPTER 3

RESULTS AND DISSECTIONS

Chapter 3

Results and Dissections

Table (3-1) Mass per Unit Area (Weight) of Fabric used

No of sample	Specification of samples	Weight (g)
1	Viscose /plain 2/2 (VP)	1.995133
2	Viscose /twill (VT)	2.078367
3	Viscose /sateen 4 (VS)	2.145033
4	Polyester /plain 2/2(PP)	1.892867
5	Polyester /twill (PT)	2.037600
6	Polyester /sateen 4(PS)	2.015567
7	cotton /plain 2/2 (CP)	2.206333
8	cotton /twill (CT)	1.879100
9	Cotton /sateen 4 (CS)	2.363100

All the 9 samples were weighed on an analytical balance. Readings were taken and weights /unit area were determined.

Table (3-2) Air Permeability of Textile Fabrics used after being exposed to UV rays

No of sample	Air Permeability cm^3/ cm^2/ sec	After 1.5hour Exposure to UV	After 2.5 hour exposure to UV	After 3.5 hour Exposure to UV
VP	6.586	6.70	6.90	7.50
VT	15.960	16.30	16.70	17.00
VS	19.500	19.60	19.70	20.00
PP	3.316	3.35	3.60	3.90
PT	11.000	11.30	12.00	12.40
PS	11.600	11.60	11.90	12.10
CP	6.732	6.90	7.20	7.40

| CT | 10.578 | 10.80 | 10.90 | 11.00 |
| CS | 14.540 | 14.60 | 14.80 | 14.95 |

The woven textile fabrics have a porous structure, the porosity is defined by the rate of free space to fibre in a given volume of fabrics. The porous areas are voids between weft and warp yarns in fabrics .The air passes through the pores from the surface of the fabrics.

The air permeability is high in the viscose followed by cotton and polyester fabrics. As shown on table (3-2) and drawn in figure (3-1) . Due to structure changes sateen 4 weave provided best air permeability than others, and it was followed by twill 2/2 and Plain 2/2 weaves. As shown on table (3-2) and drawn in Fig (3-2) .

Less number of interlacings per unit area, make a less compact fabric and inter yarn spacings will be more which allow the air to pass through freely. Hence it can be concluded that by increasing the number of interlacings, the plain woven fabrics are dense and firm making air passage more difficult.

The air permeability values increase appreciably at the beginning of exposure time for all of the examined fabrics. These results verify the effect of UV exposure on weakening of the irradiated samples and increasing the ability of air to pass through these structures and thus increasing their air permeability values (M. T. Pailthorpe 1972)

All cotton fabrics, polyester and viscose showed a continuous gradual increase in the air permeability with the time of exposure to UV rays, as shown in Figures (3-3) ,(3-4) and (3-5).

The Plain design of the polyester fabrics showed the lowest value of air permeability while the sateen design of the viscose fabric showed the highest.

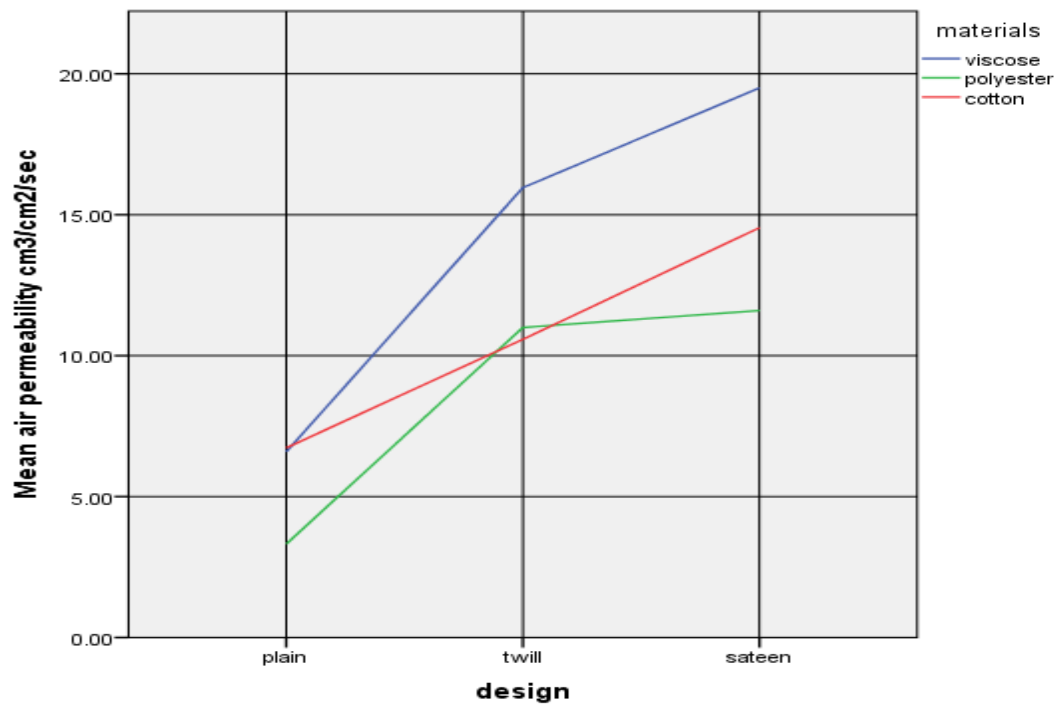Fig (3-1) the variation of air permeability of the woven fabrics with the designs of samples
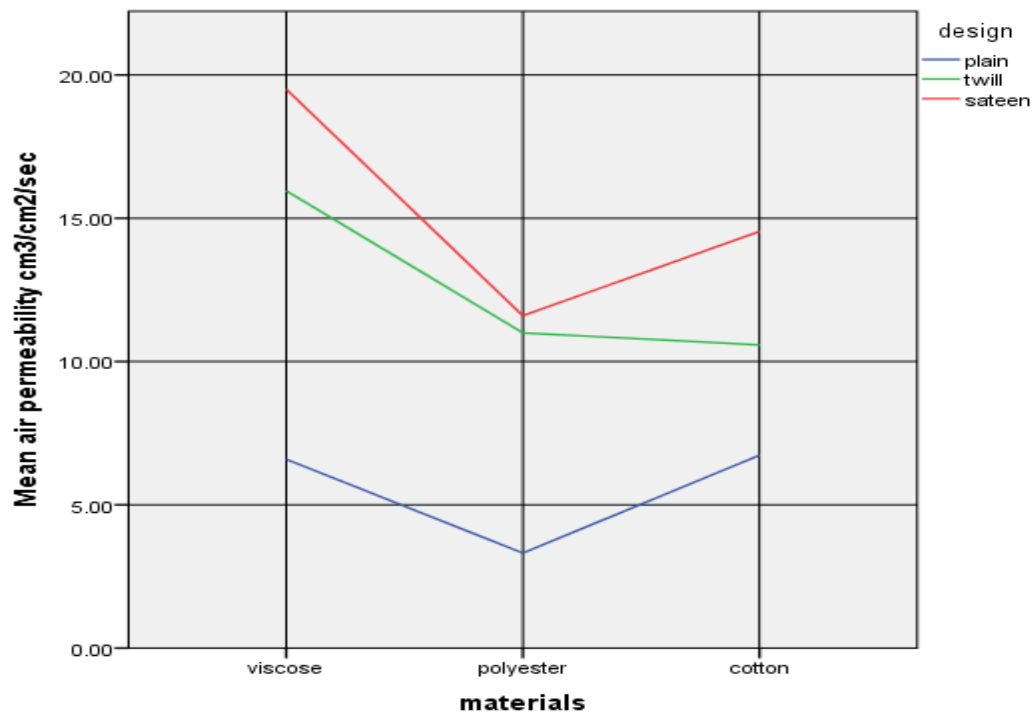

Fig (3-2) the variation of air permeability of the woven fabrics with the materials of samples
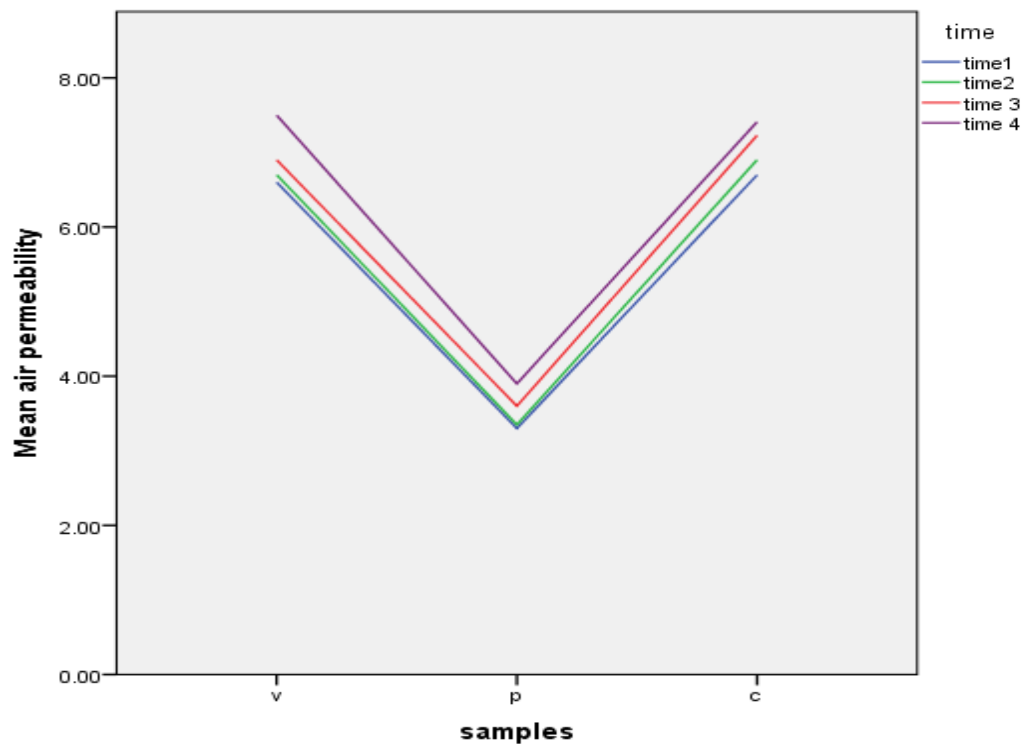
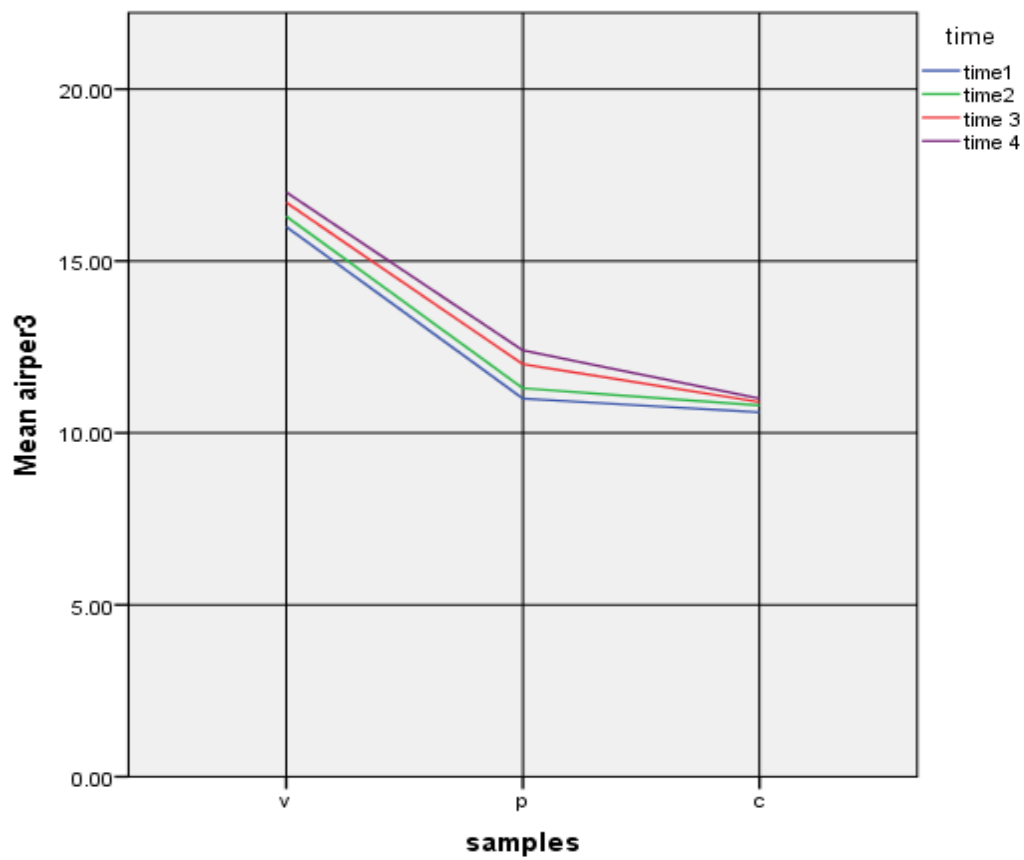Fig (3-3) relationship between exposure time to UV and Plain samples

Fig (3-4) relationship between exposure time to UV and Twill samples
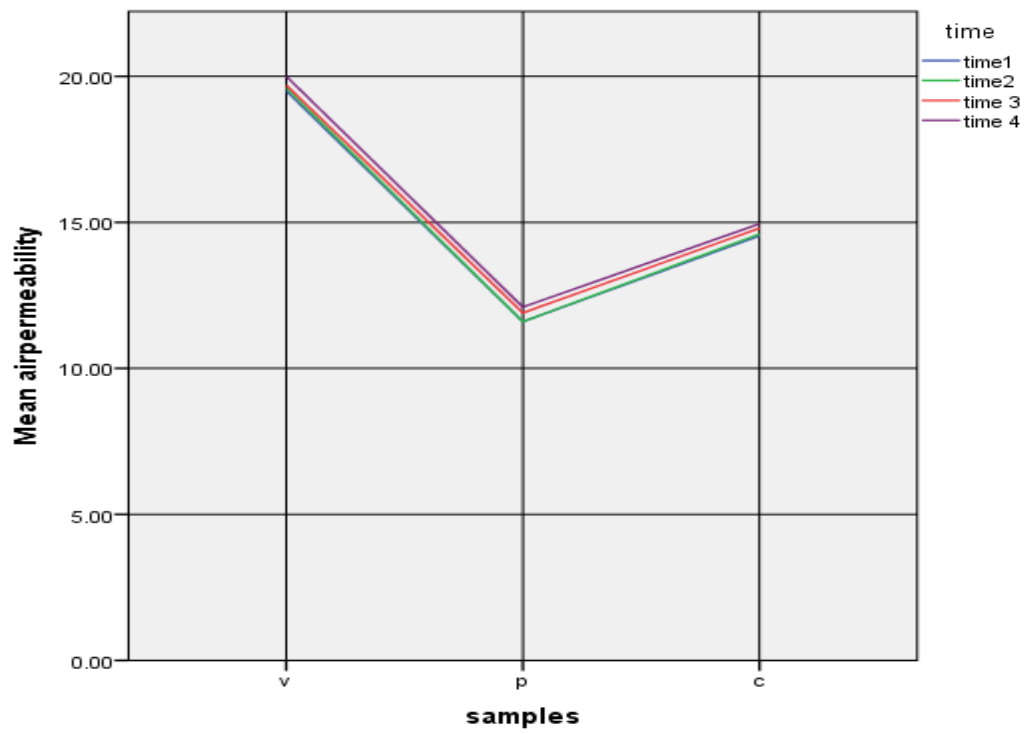
Fig (3-5) relationship between exposure time to UV and Sateen samples

Table (3-3): Abrasion Resistance of Textile Fabrics

No of sample	Abrasion Resistance	After 1.5hour	After 2.5hour	After 3.5hour
VP	118.3333	113.0000	108.0000	100.0000
VT	173.6667	162.0000	160.0000	158.0000
VS	312.3333	300.0000	196.0000	287.0000
PP	195.6667	183.0000	179.0000	176.0000
PT	211.3333	186.0000	175.0000	154.0000
PS	280.3333	244.0000	239.0000	222.0000
CP	112.0000	110.0000	108.0000	102.0000
CT	135.3333	127.0000	120.0000	117.0000
CS	146.3333	137.0000	133.0000	121.0000

Abrasion ultimately results in the loss of characteristics of performance of fabrics such as strength, but it also affects the appearance of a fabric. (Collier, B. J 1999).Abrasion first affects the fabric surface and then affects the internal structure (Ozipek, B 2003).Our experimental study on the abrasion resistance property of different weave types showed that the weave type has a significant effect. The test results indicated that low number of interlacings decrease the abrasion resistance of woven fabrics.   The results showed that the effect of weave types on abrasion resistance is significant.Sateen design got higher abrasion resistance values than others. The cotton fabric got the lowest abrasion resistance values. As shown on table (3-3) and drawn in Fig (3-6) and (3-7) .All fabrics, cotton, polyester and viscose showed continuous gradual decreases in abrasion with the increasing time of exposure to UV radiation. As shown on figures (3-8), (3-9) and (3-10).
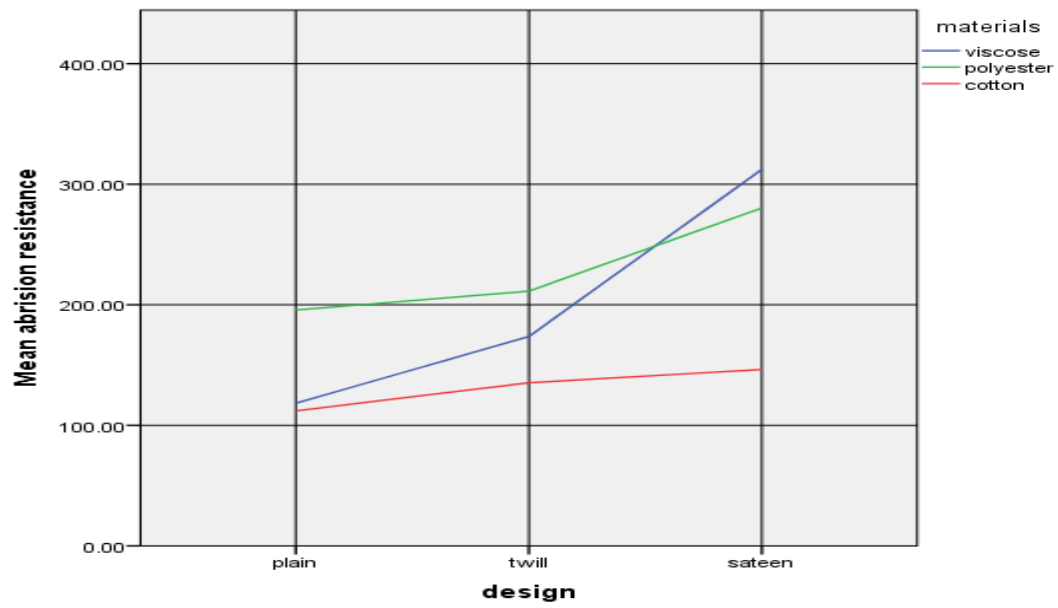
Fig (3-6) the variation of abrasion of the woven fabrics with the design of samples
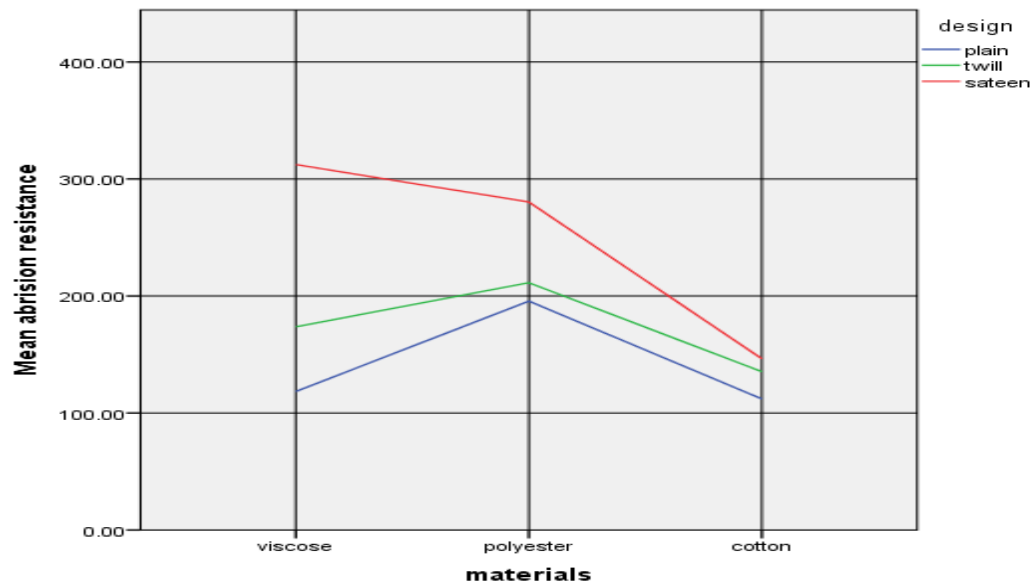
Fig (3-7) the variation of abrasion of the woven fabrics with the materials of samples
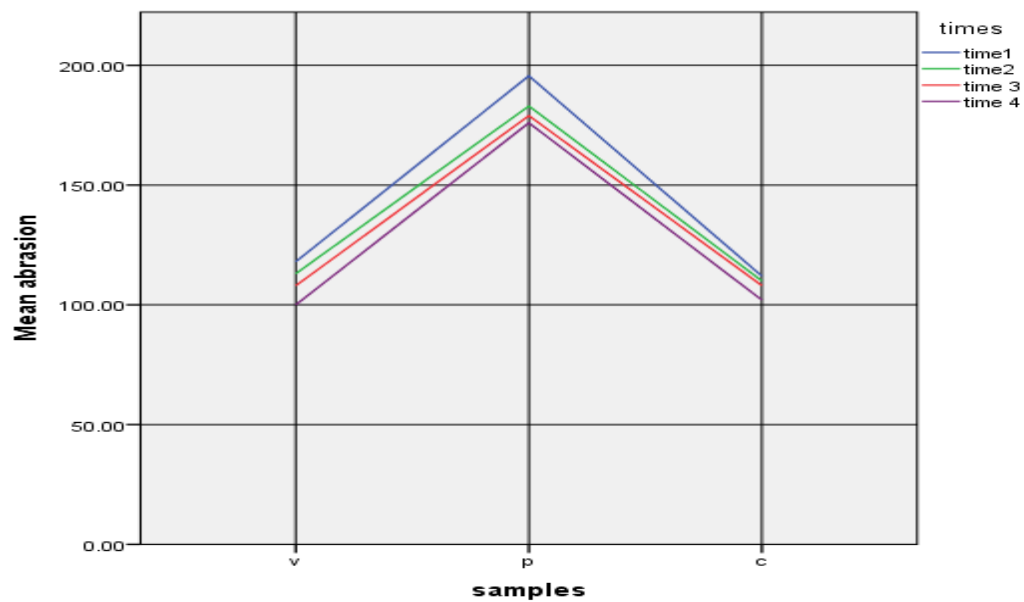
Fig (3-8) relationship between exposure time to UV and abrasion resistance of plain samples
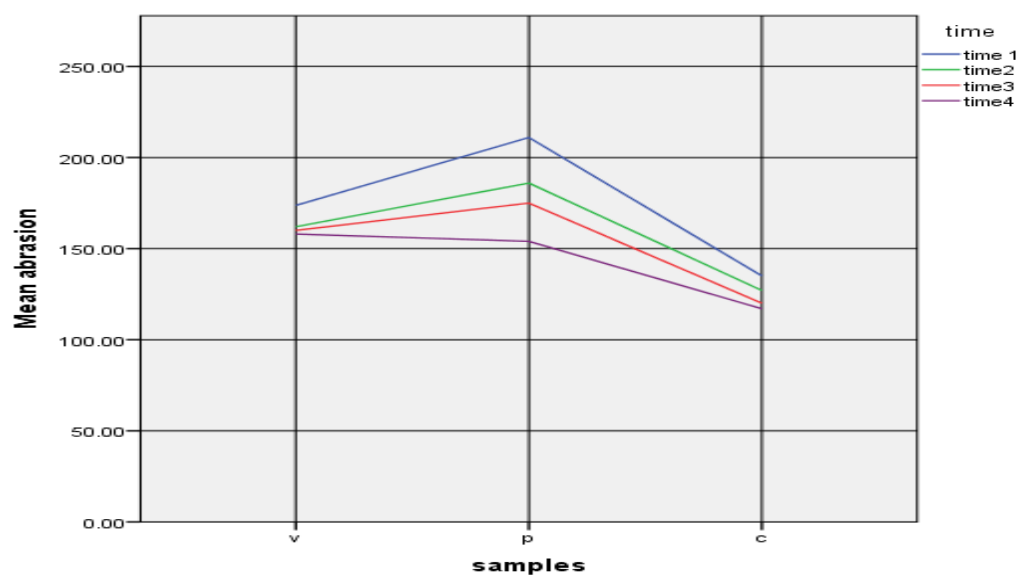
Fig (3-9) relationship between exposure time to UV and abrasion resistance of twill samples
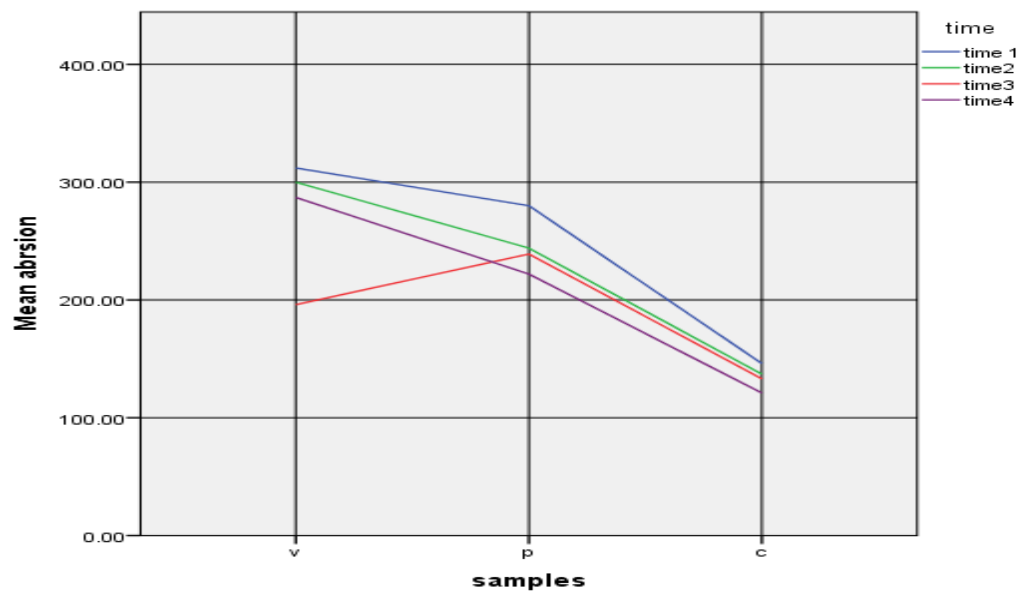
Fig (3-10) relationship between exposure time to UV and abrasion resistance of sateen samples

Table (3-4) Flexible Material Stiffness of fabrics used and the effect of exposure time on stiffness (warp direction)

No of sample	The degree of stiffness (warp direction)	After 1.5hour	After 2.5hour	After 3.5hour
VP	1.137	1.120	1.100	1.000
VT	1.246	1.200	1.150	1.010
VS	1.179	1.160	1.100	1.000
PP	1.229	1.020	1.010	1.000
PT	1.120	1.100	1.020	1.000
PS	1.309	1.210	1.100	1.060
CP	1.147	1.120	1.100	1.020
CT	1.052	1.030	1.010	1.000
CS	1.063	1.020	1.010	0.960

Table (3-5) Flexible Material Stiffness of fabrics used and the effect of exposure time on stiffness (weft direction)

No of sample	The degree of stiffness (weft direction)	After 1.5hour	After 2.5hour	After 3.5hour
VP	1.197	1.160	1.150	1.120
VT	1.454	1.430	1.300	1.200
VS	1.351	1.300	1.210	1.200
PP	1.324	1.210	1.100	1.010
PT	1.324	1.200	1.180	1.140
PS	1.410	1.200	1.180	1.120
CP	1.323	1.200	1.110	1.100
CT	0.977	0.850	0.820	0.700
CS	1.299	1.220	1.200	1.120

It was found that there is a decrease in the degree of stiffness of all fabrics after exposure to UV at warp and weft direction. The plain weave showed high stiffness values in cotton fabrics due to the limping surface while sateen design of the polyester fabrics showed the highest stiffness value. The lowest values of stiffness is showed by the twill design of the cotton fabric in warp direction .As shown on Fig (3-11) and (3-13).

The twill weave of viscose fabric showed the highest stiffness value. The twill design of the cotton fabric showed the lowest values of stiffness in the weft direction as shown in Fig (3-12) and (3-14).

Stiffness is the relationship between the modulus of elasticity and the area of the cross section of fibers.

Free longitudinal damped oscillations occur in the sample due to the given load. Oscillations depend on the properties of the materials, in particular its elasticity.

All fabrics, cotton, polyester and viscose showed continuous gradual decrease in the stiffness with increasing time of exposure to UV radiation, as shown on table (3-4) and (3-5) and drawn in figures (3-15) to Fig (3-20) .
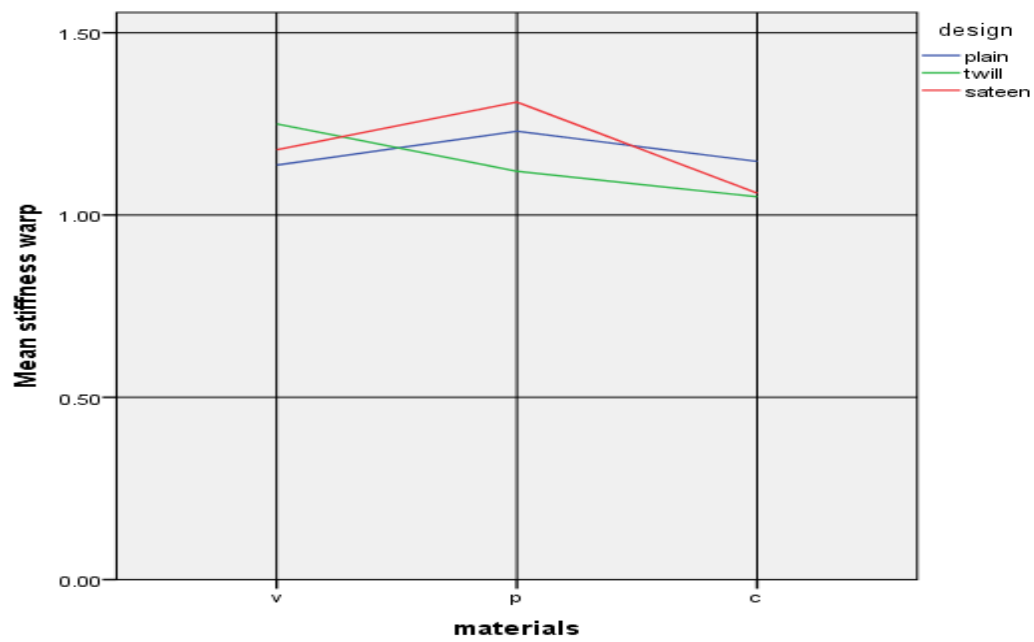
Fig (3-11) the variation of stiffness in warp direction of the woven fabrics with the materials of samples
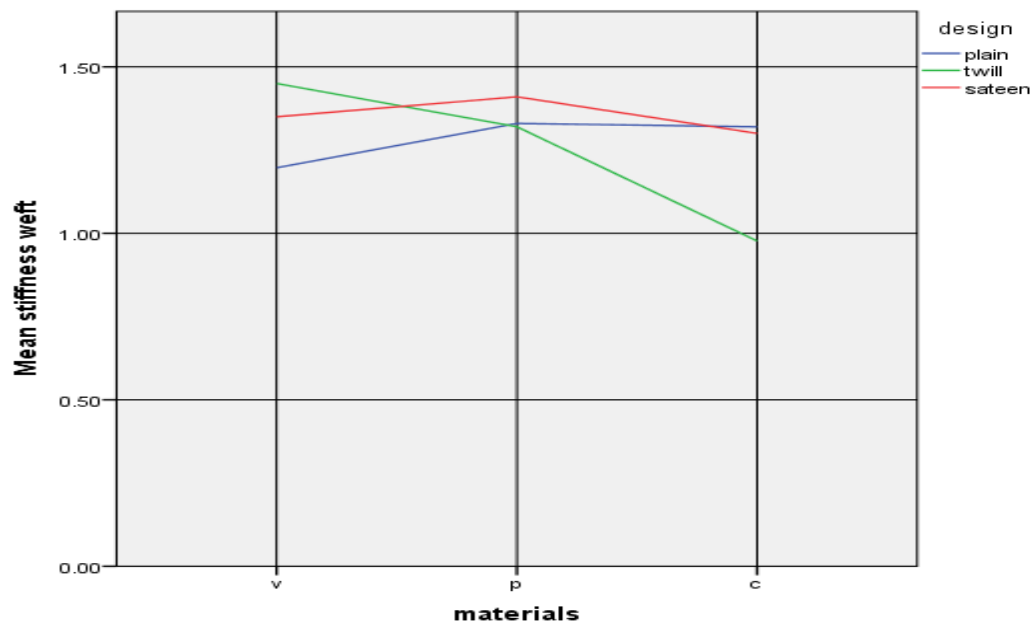
Fig(3-12) the variation of stiffness in weft direction of the woven fabrics with the materials of samples
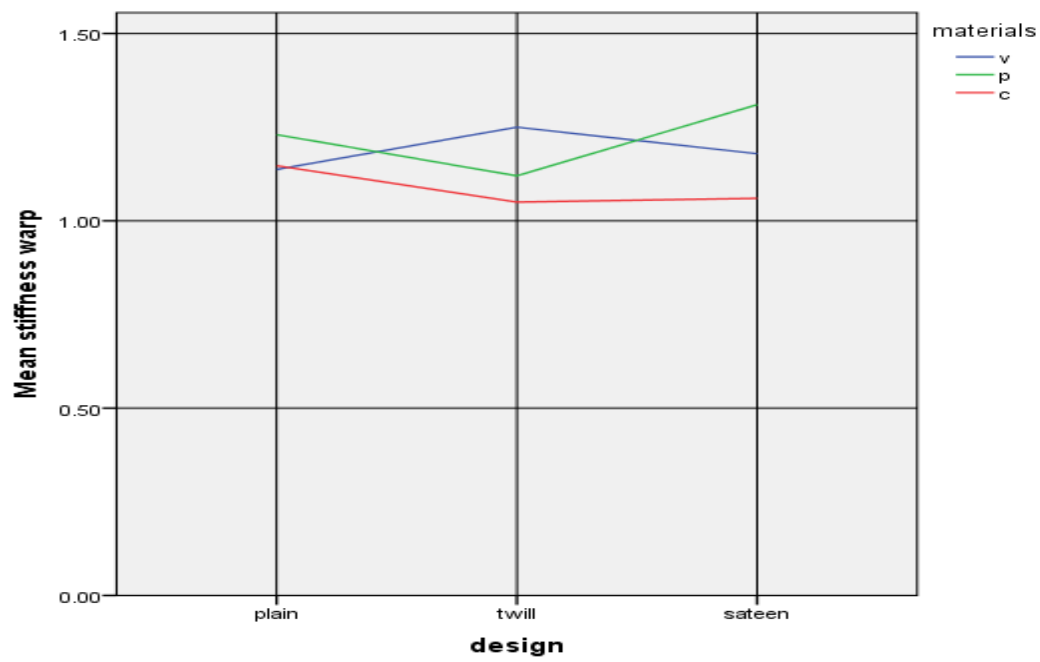
Fig (3-13) the variation of stiffness in warp direction of the woven fabrics with the design of samples
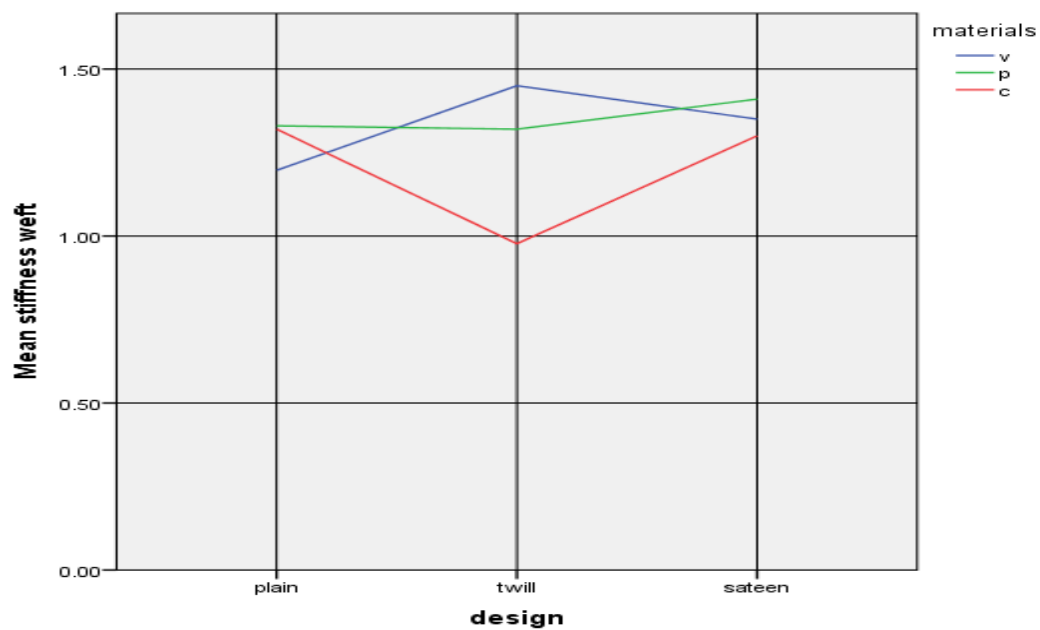
Fig (3-14) the variation of stiffness in weft direction of the woven fabrics with the design of samples
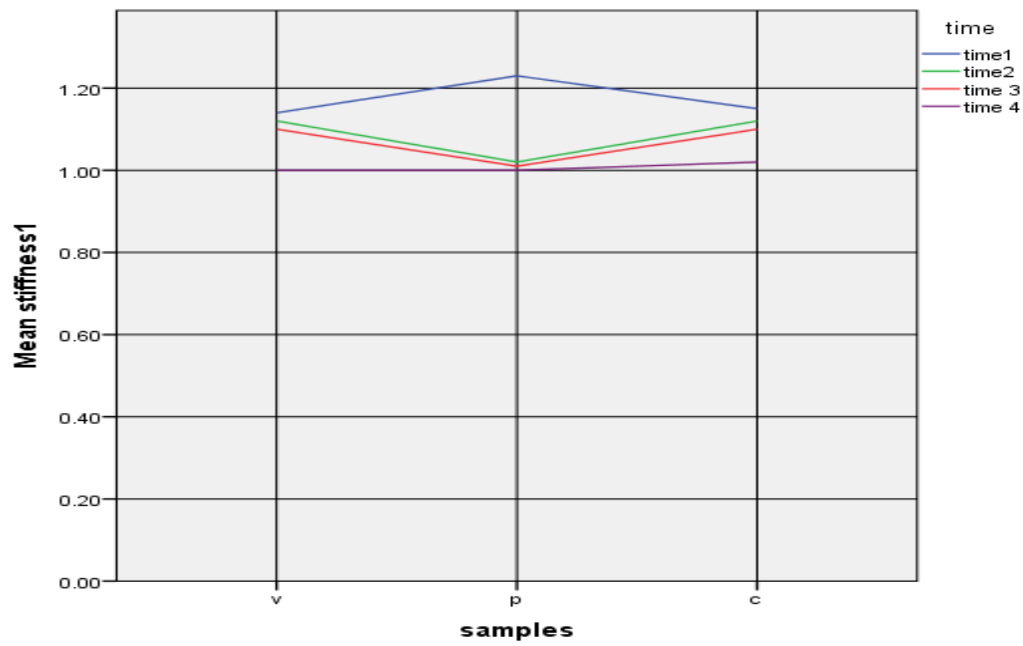
Fig (3-15) Effect of UV radiation on the stiffness in warp direction with the change of exposure time and plain samples design
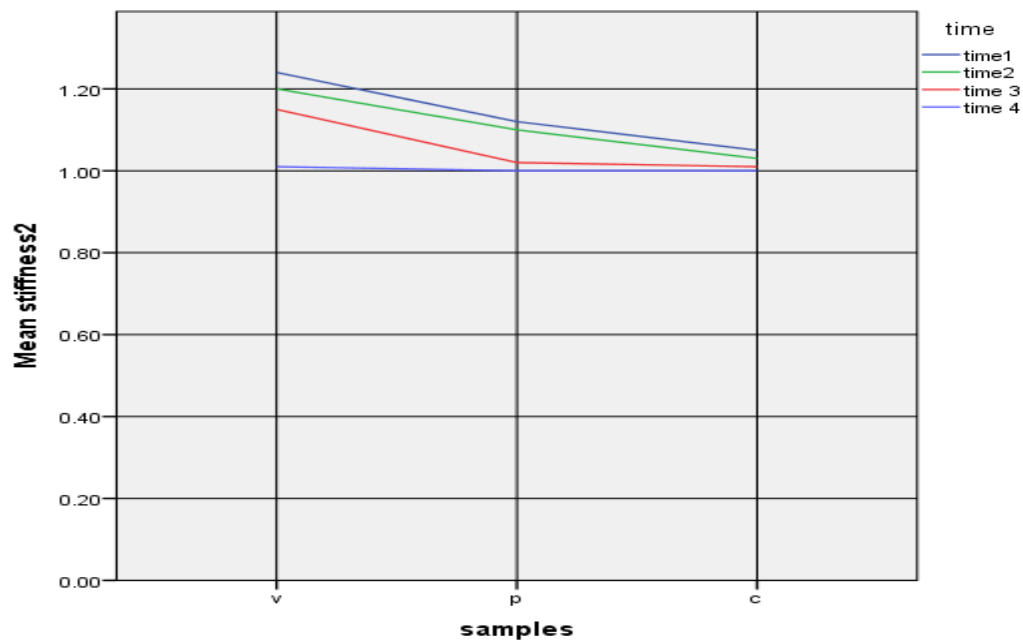
Fig (3-16) Effect of UV radiation on the stiffness in warp direction with the change of exposure time and twill samples design
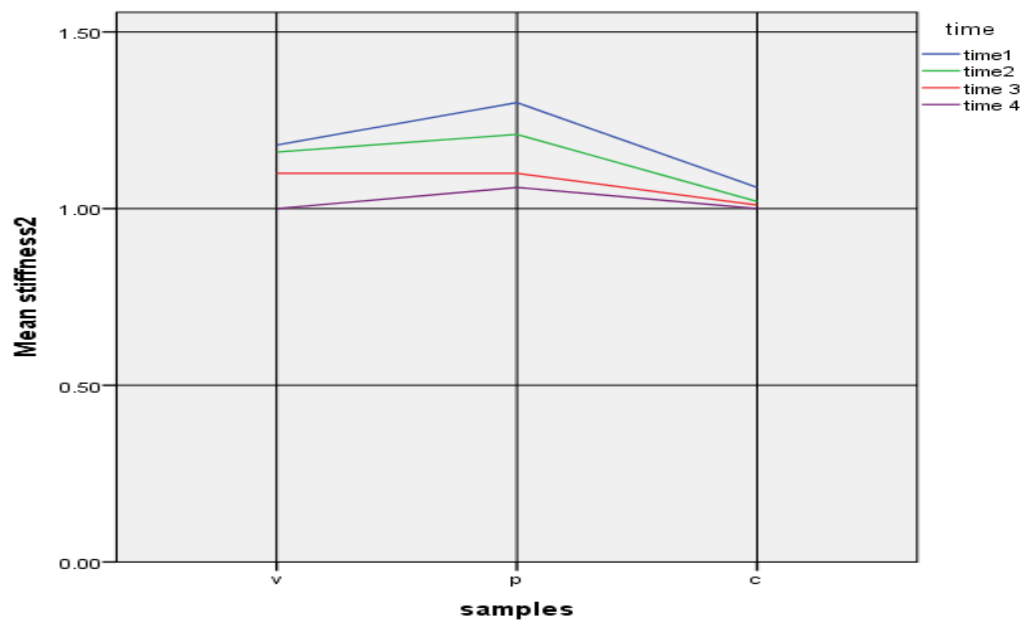
Fig (3-17) Effect of UV radiation on the stiffness in warp direction with the change of exposure time and sateen samples design
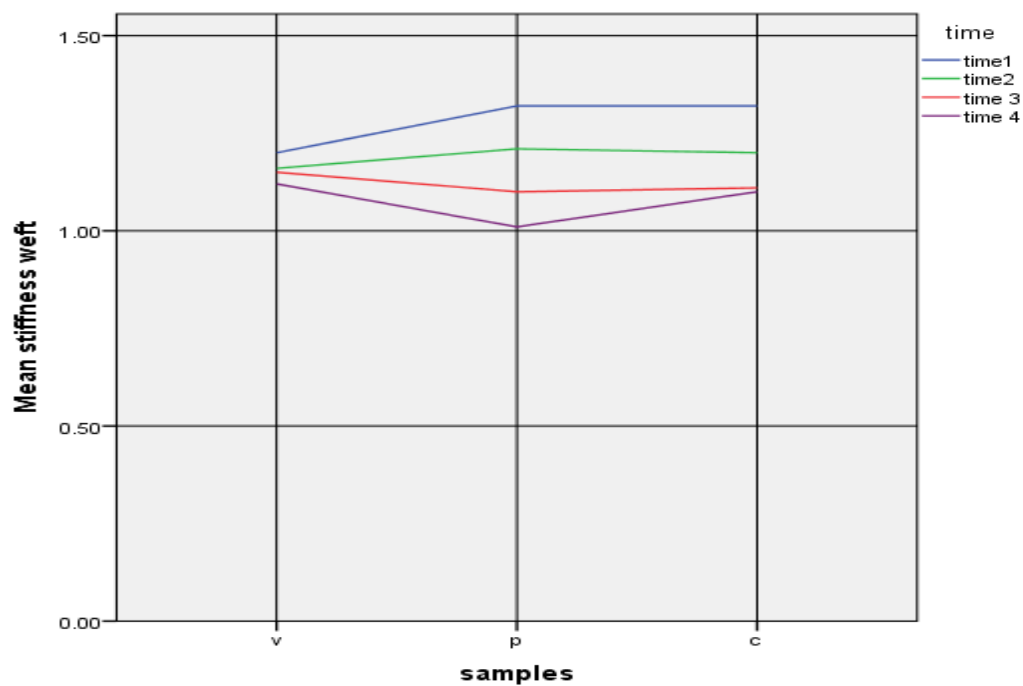
Fig (3-18) Effect of UV radiation on the stiffness in weft direction with the change of exposure time and plain samples design
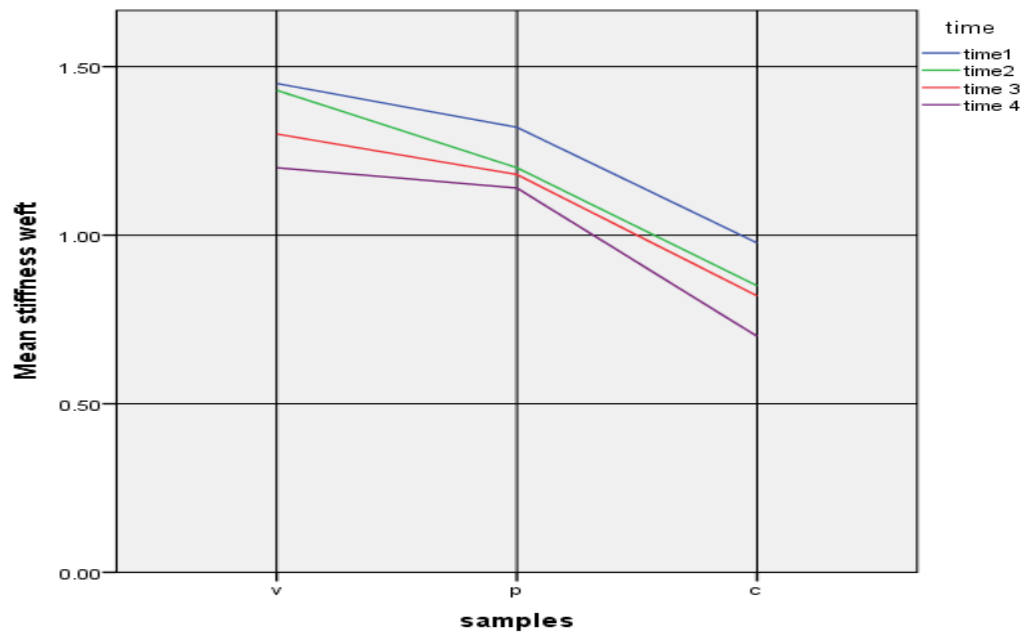
Fig (3-19) Effect of UV radiation on the stiffness in weft direction with the change of exposure time and twill samples design
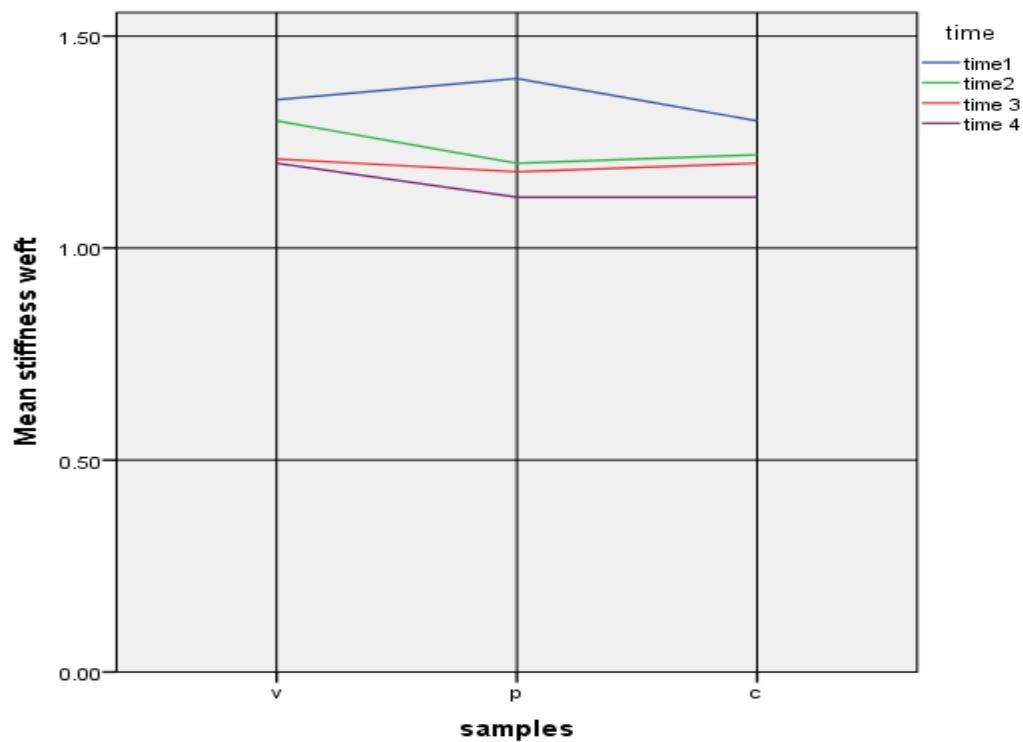
Fig (3-20) Effect of UV radiation on the stiffness in weft direction with the change of exposure time and sateen samples design

Breaking Force and Elongation of Textile Fabrics (Strip Method)

Key
1 force
2 maximum force
3 force at rupture
4 pretension
5 elongation at max. force
6 elongation at rupture
7 elongation
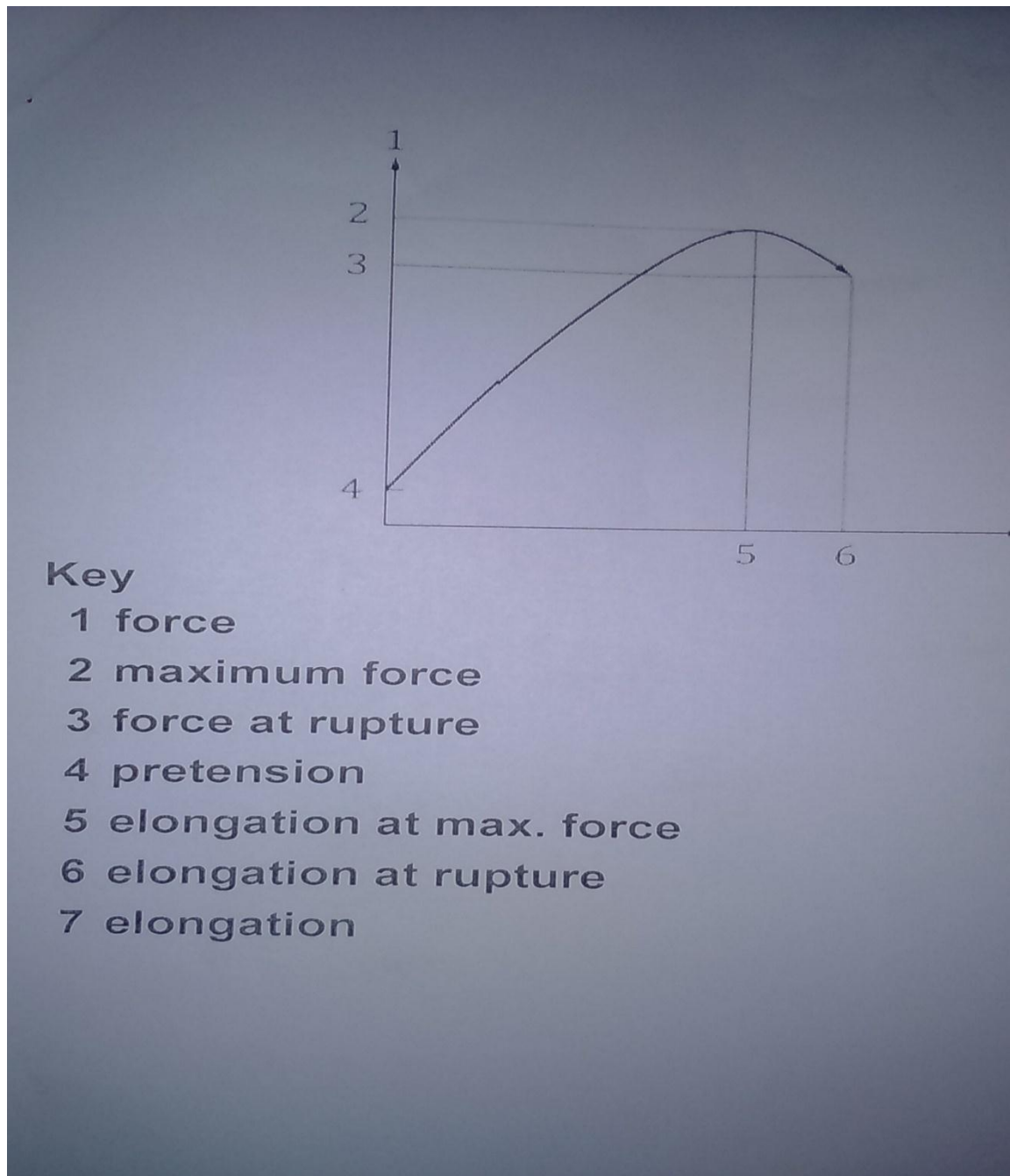
The breaking force and elongation results for the three specimens tested are obtained by using the grab test method. The breaking force (maximum force) is marked for all specimens. Examination of the specimens after being tested shows that the tests were Successful in determining the breaking force and the percentage elongation of the fabric. Specimen preparation is extremely important in acquiring

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accurate results. A single fiber can significantly affect the reliability and repeatability of the results. As shown on table (3-6).
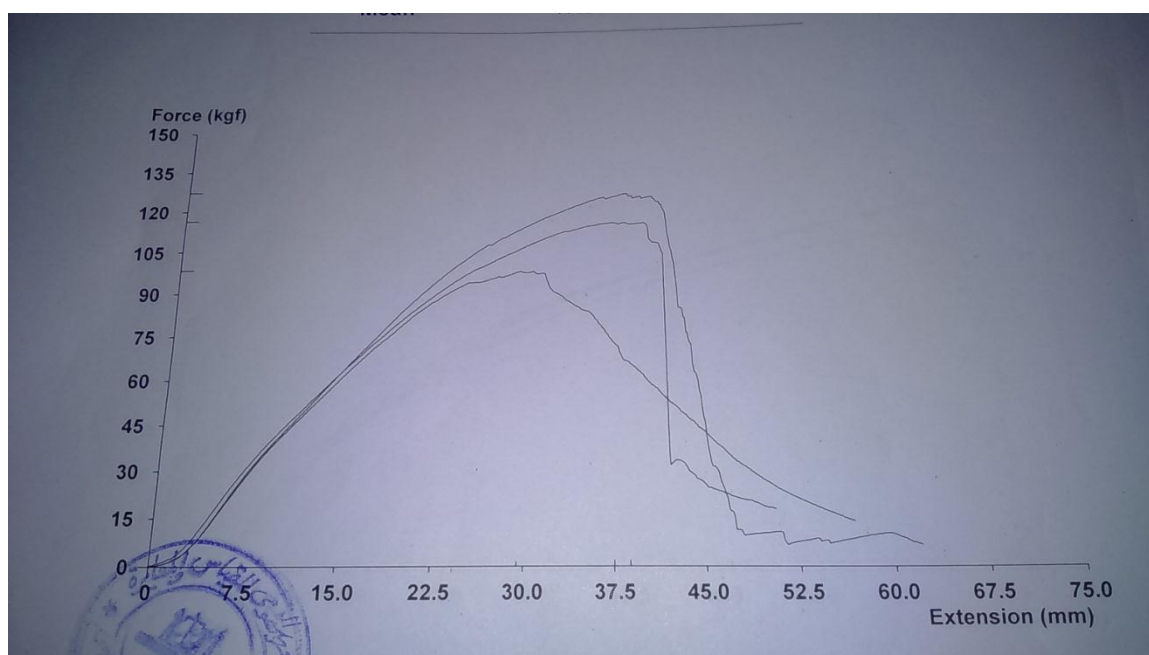
Table (3-6) breaking force of fabrics used and the effect of exposure time on breaking force

No of sample	Breaking force	After 1.5hour	After 2.5hour	After 3.5hour
VP	52.1	47.0	44.0	40.0
VT	64.3	64.0	60.0	53.0
VS	54.7	54.1	52.0	50.1
PP	124.6	120.0	112.0	110.23
PT	114.0	112.0	104.0	100.0
PS	117.1	115.2	112.0	107.1
CP	54.0	48.6	46.9	43.5
CT	40.74	40.0	37.2	35.0
CS	80.9	77.0	76.1	73.0

Table (3-7) elongation of fabrics used and the effect of exposure time on breaking force

No of sample	Elongation %	After 1.5hour	After 2.5hour	After 3.5hour
VP	7.68	7.30	7.01	6.00
VT	18.33	18.00	17.30	17.00
VS	17.94	17.30	17.05	16.90
PP	21.26	21.01	20.65	20.00
PT	17.63	17.00	16.69	16.10
PS	30.61	30.00	28.20	27.90
CP	16.70	16.00	15.60	15.01
CT	8.11	7.96	7.65	6.95
CS	10.61	10.01	9.30	9.03

The tested samples become more solid, rough and brittle as a consequence of exposure to UV .Table (3-6) shows that the rate of loss in the breaking force increases by increasing the exposure time. This amount of energy absorbed was enough to break the links between the atoms making up the molecules of cellulose and leading to a decrease in breaking force.

The changes in the mechanical properties of the examined fabric during exposure to UV reflect not only the changes in the chemical structure of the polymer system but also the sub-molecular organization and its morphology [Shao et al., 1999].

The Plain polyester fabrics got the highest breaking force, followed by cotton and then viscose. The sateen design of the viscose fabric got the lowest value, as shown on table (3-6) and drawn in figures (3-21) and (3-22).

Figures (3-23),(3-24) and (3-25) show that all the samples showed a decrease in breaking force after exposure to UV . Table (3-7) shows the results of elongation

of the samples after exposure to UV for various periods. Exposure to UV with time shows significant decrement as drawn in figures (3-26), (3-27) and (3-28). This can be attributed to the oxidation and slight melt of fibers. Decrement of breaking strength was not a drastic decrement because the UV act predominantly on the fabric surface exposed.

When a fabric is stretched in one direction the crimp in that direction declines. Fabric is relatively easy to expand during crimp diminishing. After that, the yarn material starts bearing the force which would trim down the extension of the fabric. Meanwhile, while crimp is decreasing in one direction it amplifies in the reverse direction. Owing to the crimp, however, having higher interlacement, plain weave fabrics have the maximum crimp. So very little amount of slippage of fibres occurred in yarns. The yarns are not held in firmly in sateen weave structure as in the plain weave. This provides greater strength.
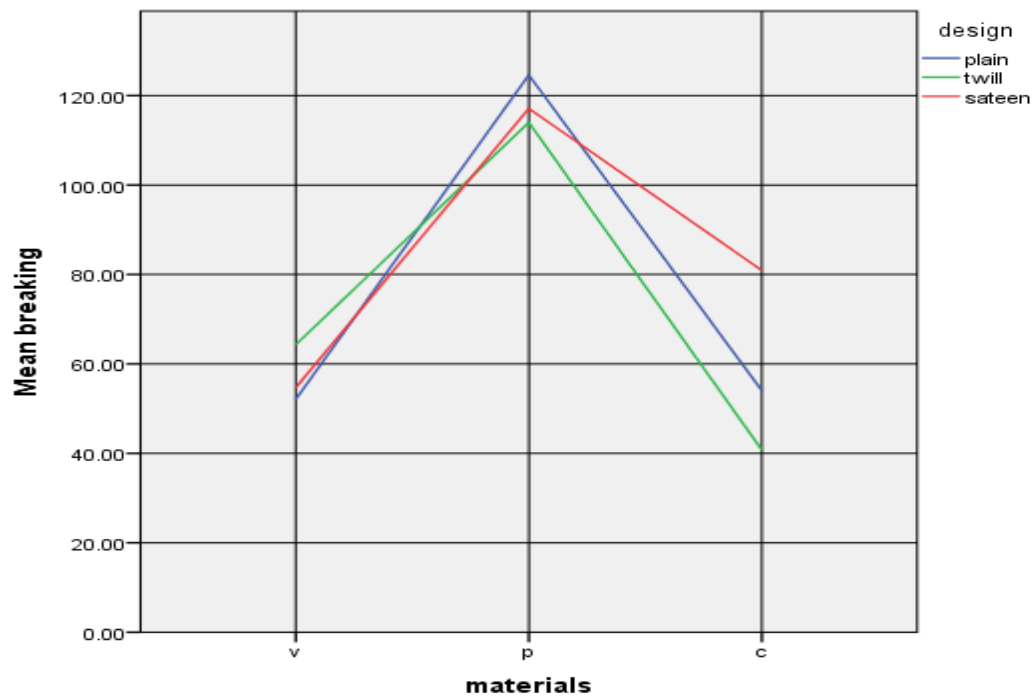
Fig (3-21) the variation of breaking force of the woven fabrics with the materials of samples
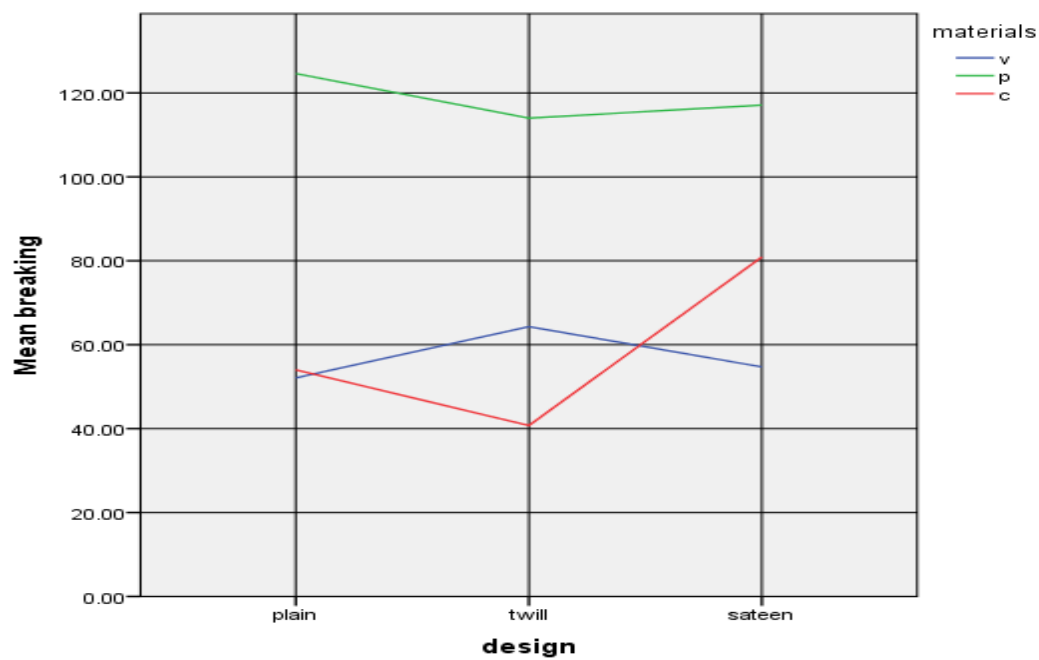
Fig (3-22) the variation of breaking force of the woven fabrics with the design of samples
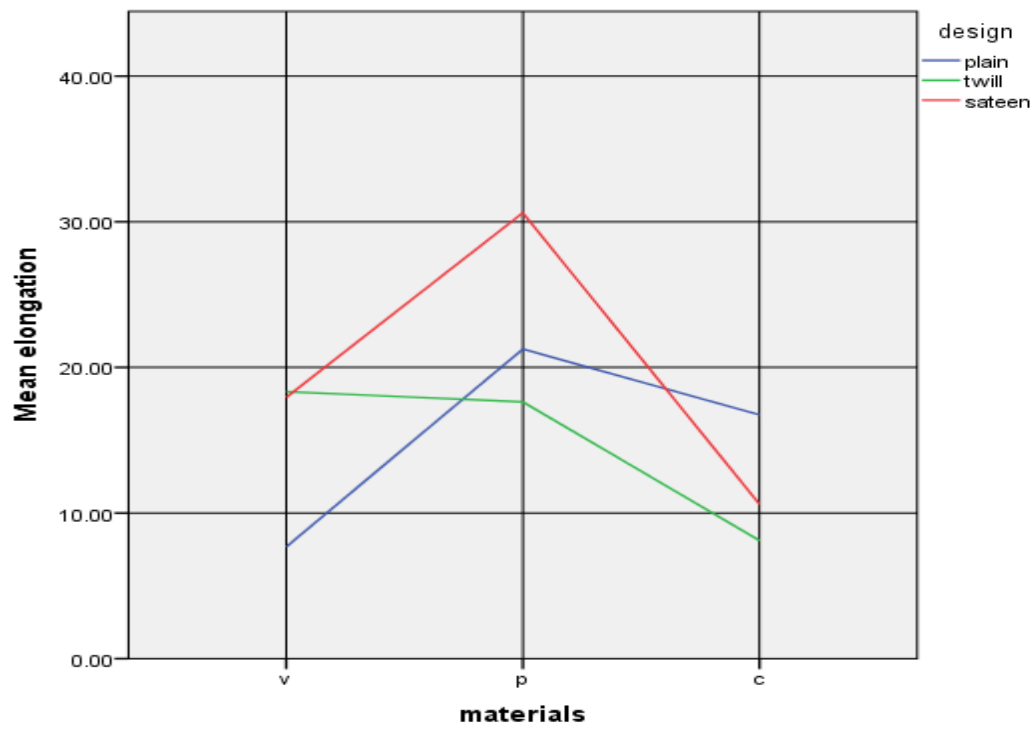
Fig (3-23) the variation of elongation of the woven fabrics with the materials of samples
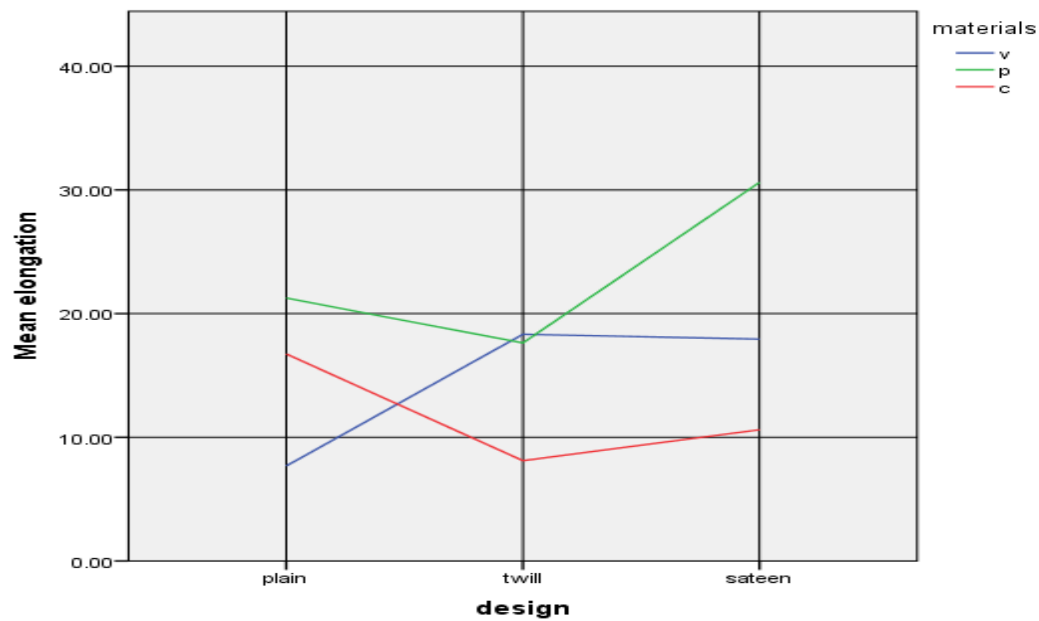
Fig (3-24) the variation of elongation of the woven fabrics with the design of sample
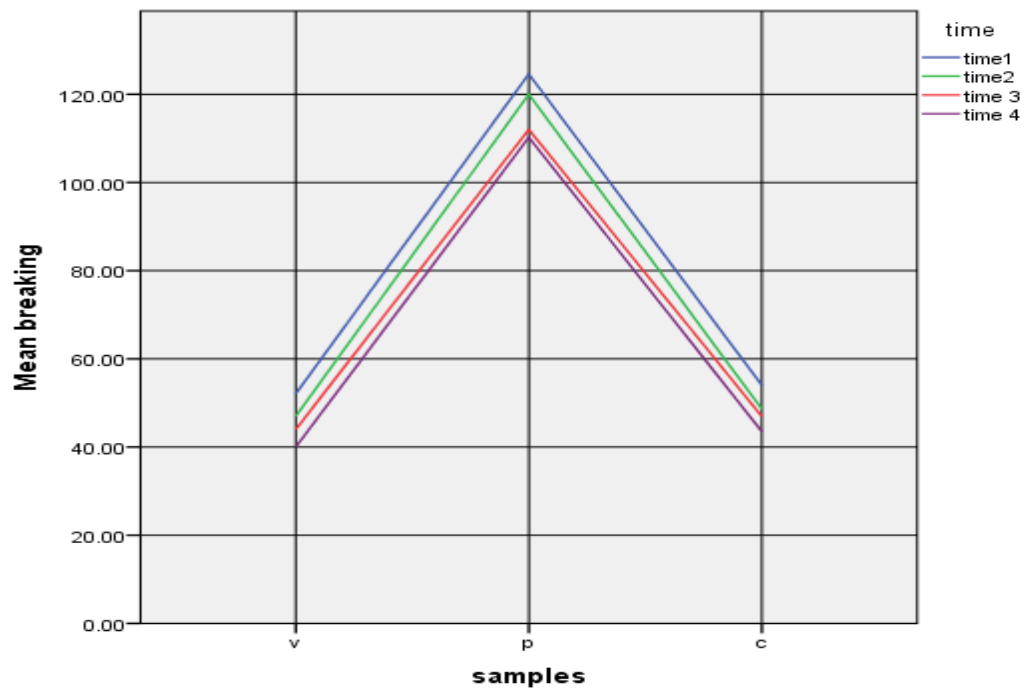
Fig (3-25) Effect of UV radiation on the breaking force with the change of exposure time and plain samples design

Fig (3-26) Effect of UV radiation on the breaking force with the change of exposure time and twill samples design

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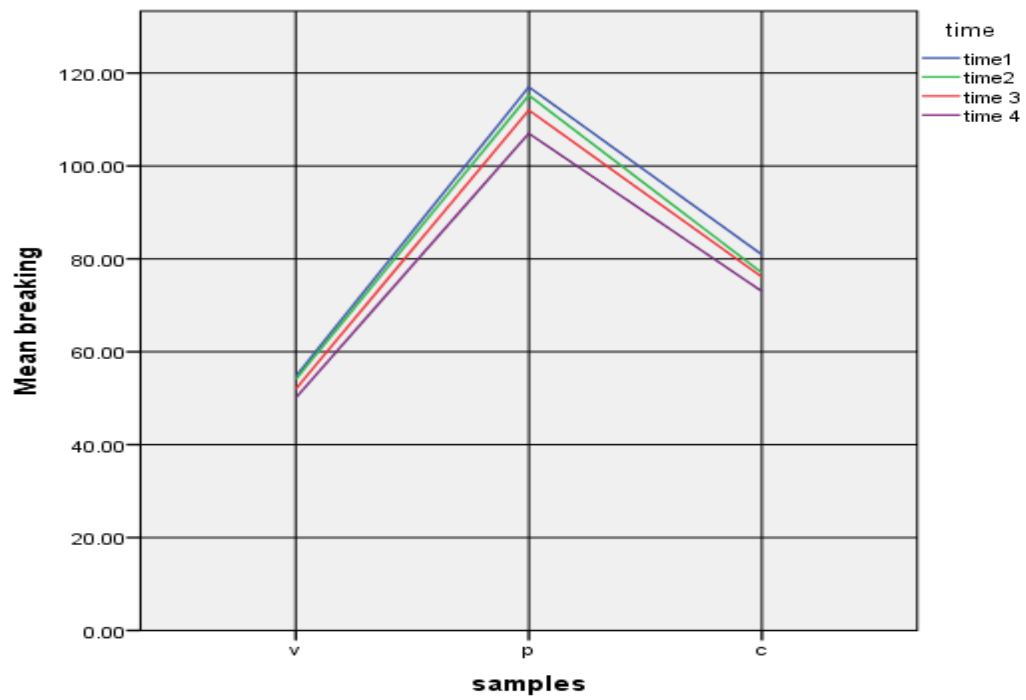
Fig (3-27) Effect of UV radiation on the breaking force with the change of exposure time and sateen samples design
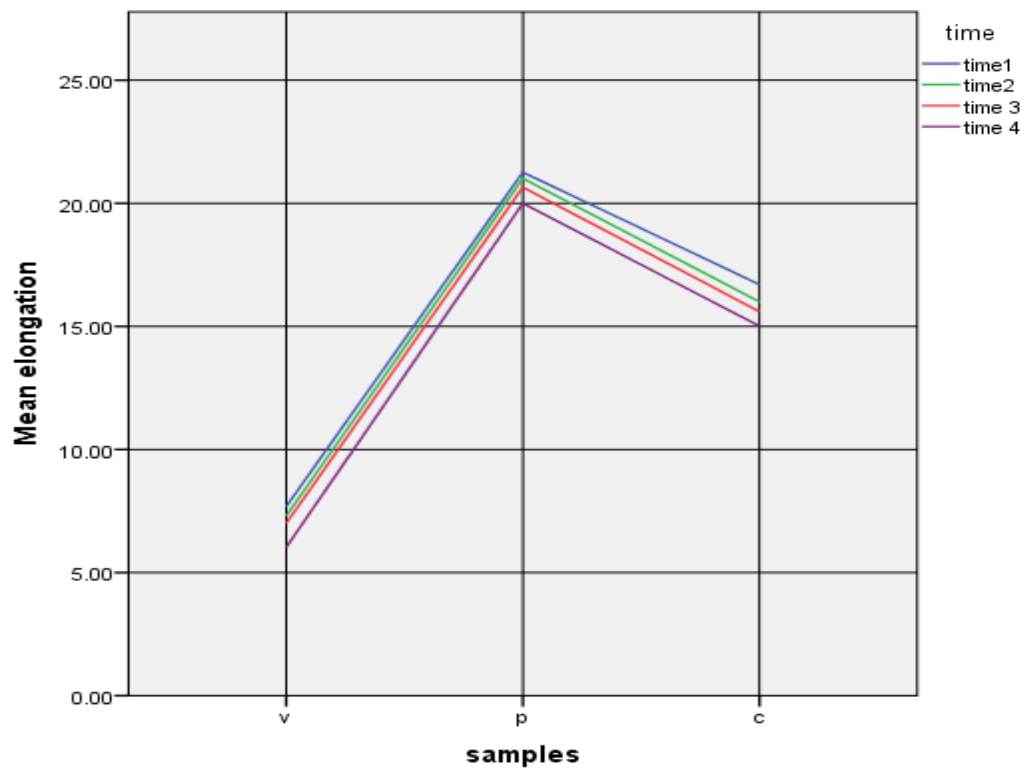
Fig (3-28) relationship between elongation and time of exposure to UV (plain design)
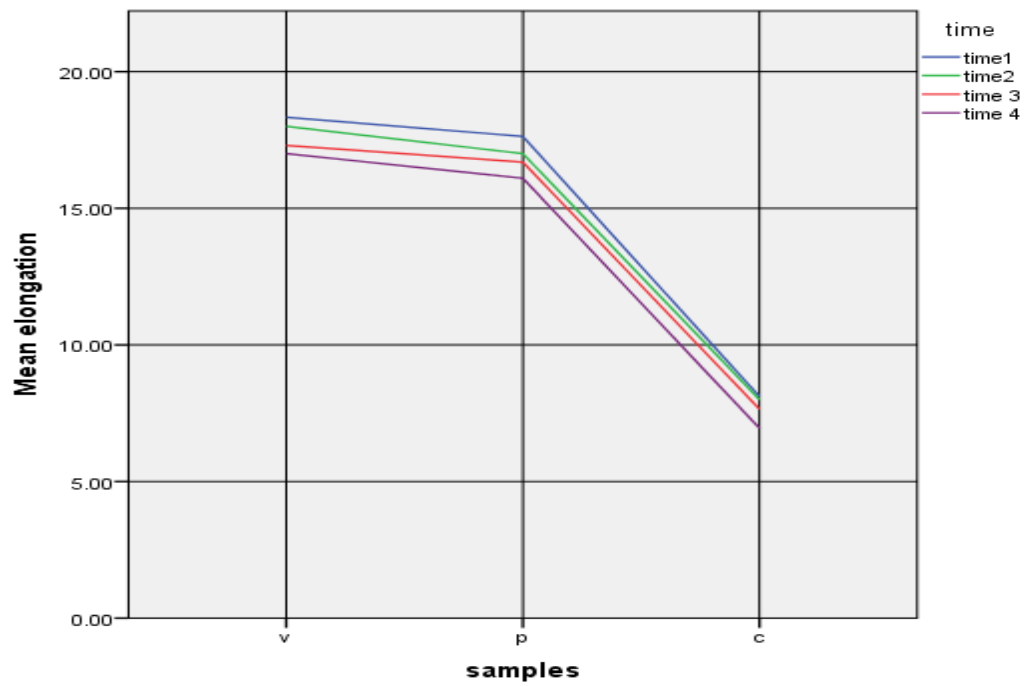
Fig (3-29) relationship between elongation and time of exposure to UV (twill design)
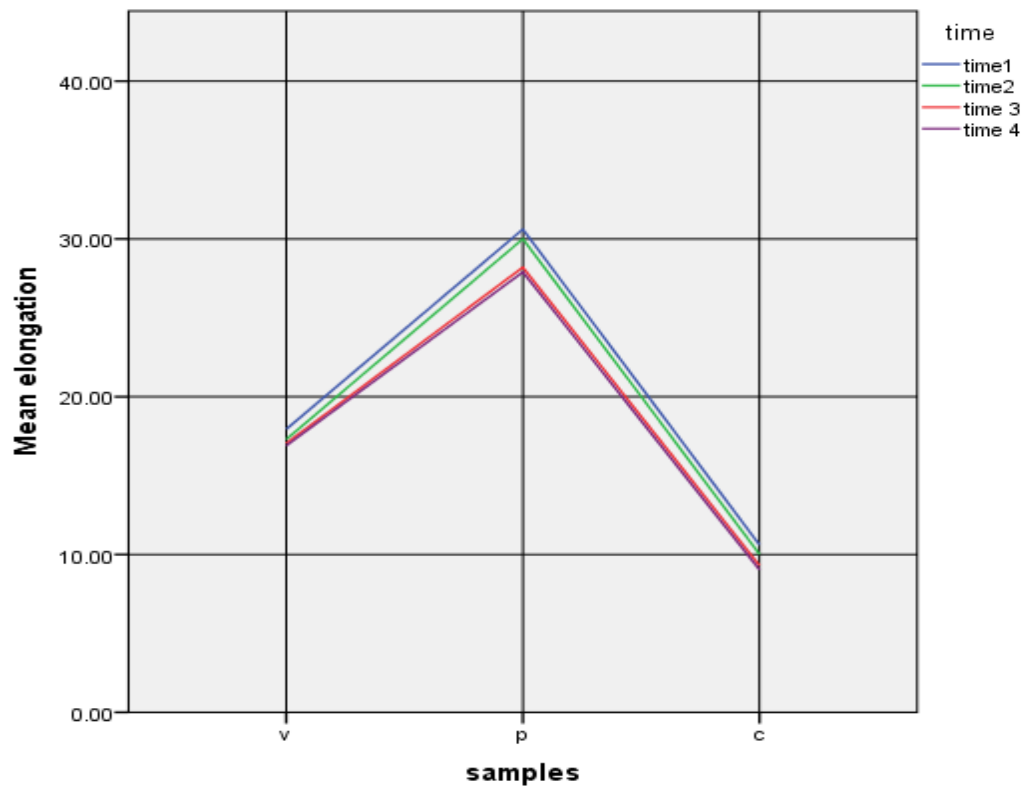
Fig (3-30) relationship between elongation and time of exposure to UV (sateen design)

Table (3-8) Ultraviolet protection factor of Textile Fabrics used after exposed to UV rays

samples	UPF	After1hour	After2hour	After3 hour
VP	71.74	65.00	63.00	60.35
VT	33.77	32.77	29.14	29.00
VS	46.79	46.00	45.00	44.00
PP	70.31	70.00	65.00	63.01
PT	63.71	62.21	59.95	57.00
PS	91.93	90.10	87.23	85.12
CP	43.08	43.00	41.01	40.64
CT	39.29	38.23	37.50	34.10
CS	75.13	66.91	64.47	57.83

UV radiation is one of the major causes of degradation of textile materials. It is due to excitations in some parts of the polymer molecules leading to a gradual loss of integrity that depends on the nature of the fibres. Because of the very large surface Volume ratio, textile materials are susceptible to influences from light and other environmental factors.

Interlacement of yarns creates pores between yarns. The value of UPF increases with the increase in fabric density and thickness for similar constructions .It is dependent on fabric porosity (Achwal W.B2000).

A high degree of correlation exists between UPF and fabric porosity, but is also influenced by the nature of fibres (Algaba I 2004) .when pores between yarns are smaller, thus more radiation is blocked .Ultraviolet protective factor is strongly dependent on the physical and chemical structure of the fibres. The chemical nature of the fibres influences the values of UPF. A natural fibre like cotton has lower degree of absorption of ultraviolet radiation than synthetic fibres (Djam M 2001,Schuicrer M 1997).

In Fig (3-32) Polyester has high ultraviolet protection value followed by cotton and viscose .The UPF dropped in all samples after exposure to UV radiation. As shown on table (3-8) and drawn in figures (3-33), (3-34) and (3-35). Fig (3-31) show that the sateen design has the highest ultraviolet protection value and the twill has the lowest one.

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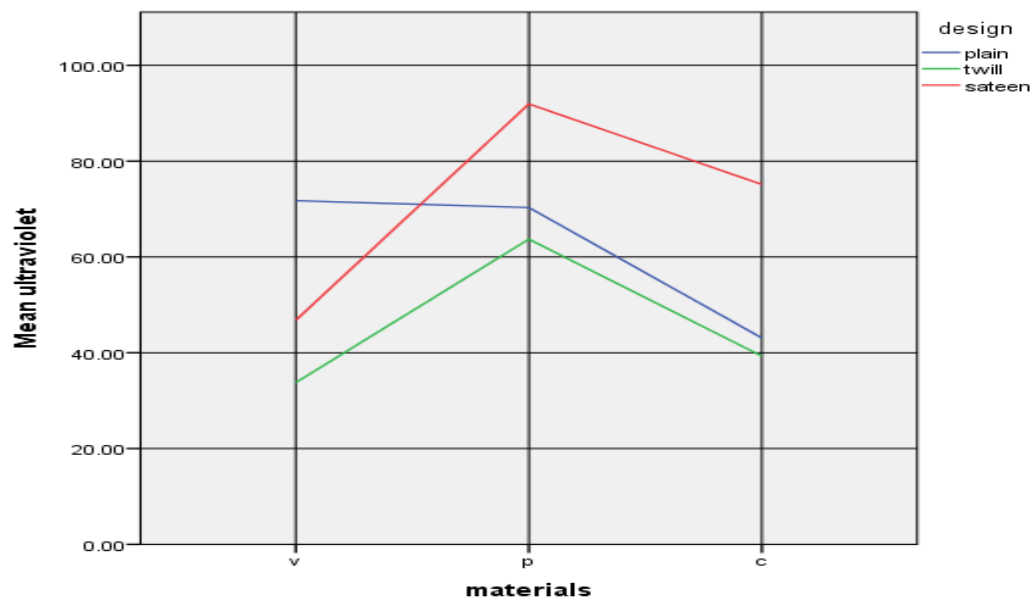
Fig (3-31) the variation of UPF of the woven fabrics with the materials of samples
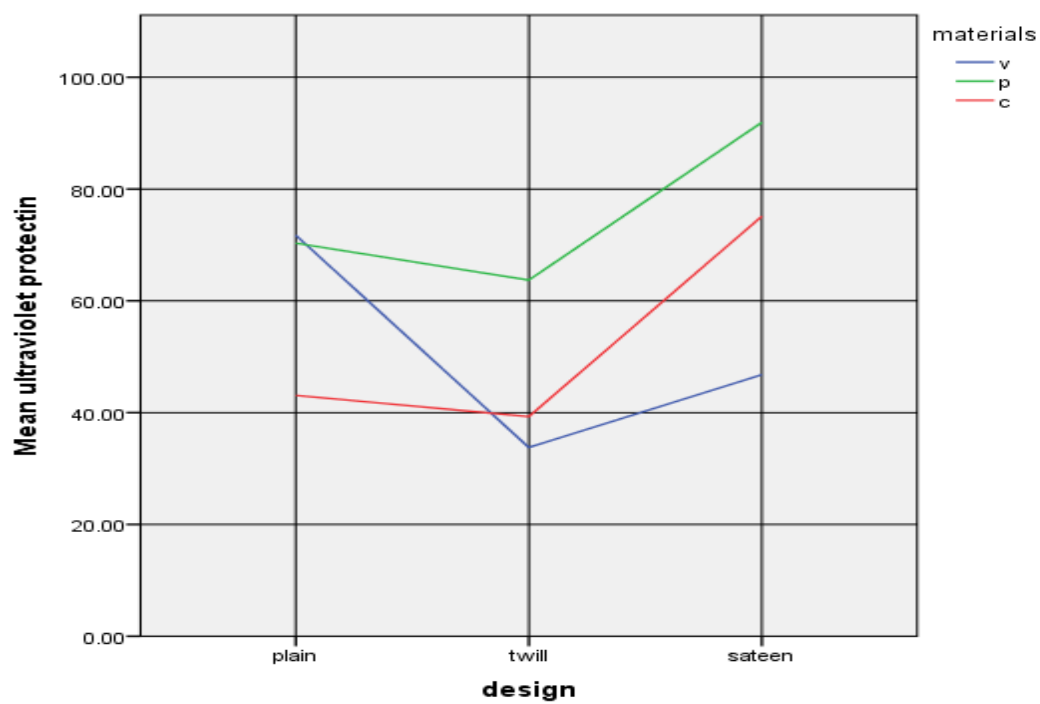

Fig (3-32) relation between design of samples and UPF
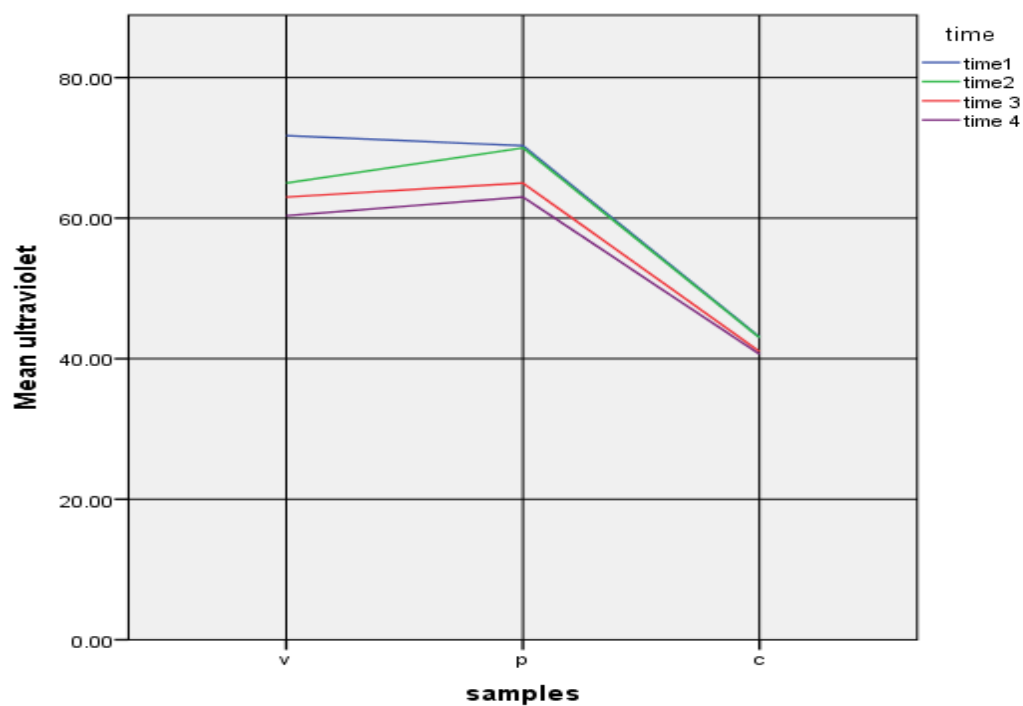
Fig (3-33) Effect of UV radiation on the UPF with the change of exposure time (plain design)
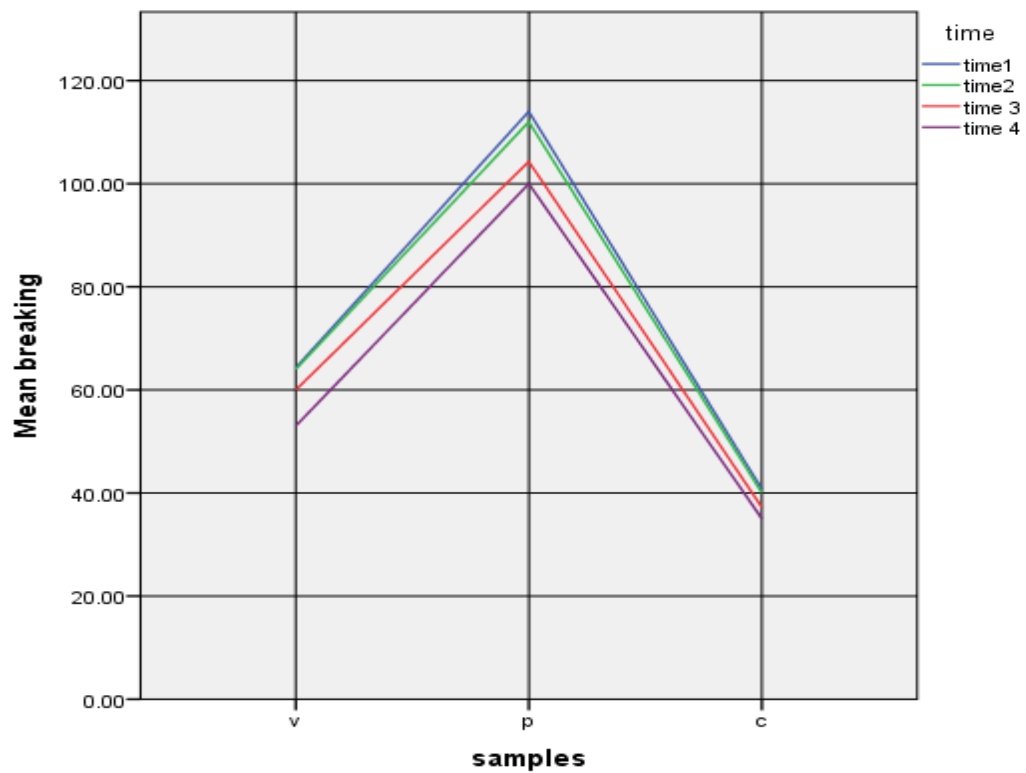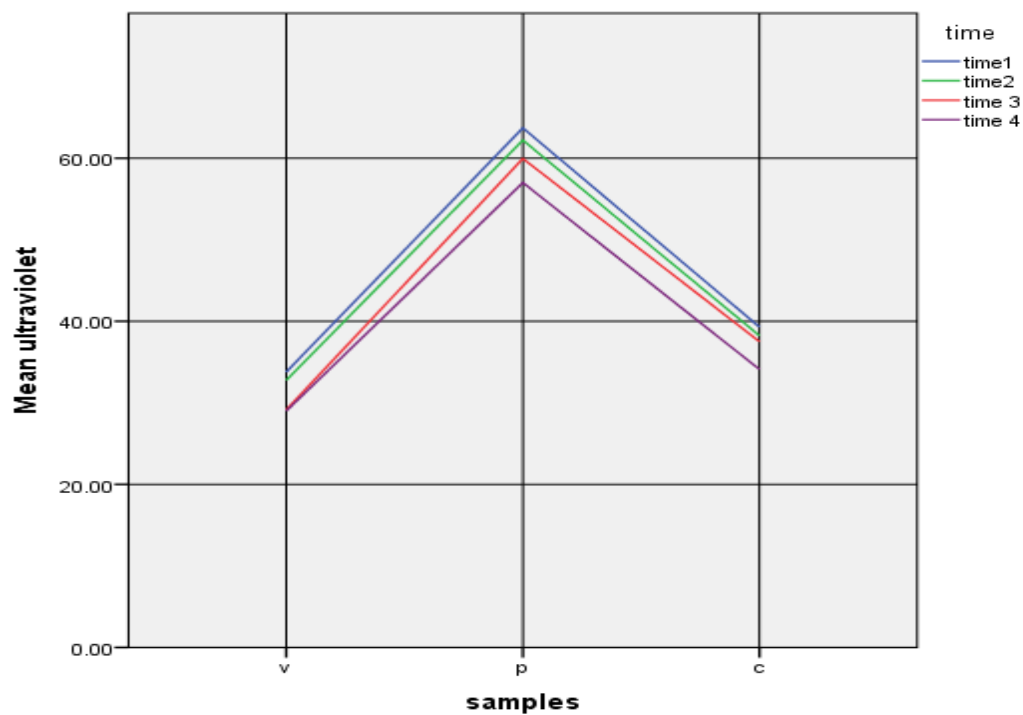

Fig (3-34) Effect of UV radiation on the UPF with the change of exposure time (twill design)
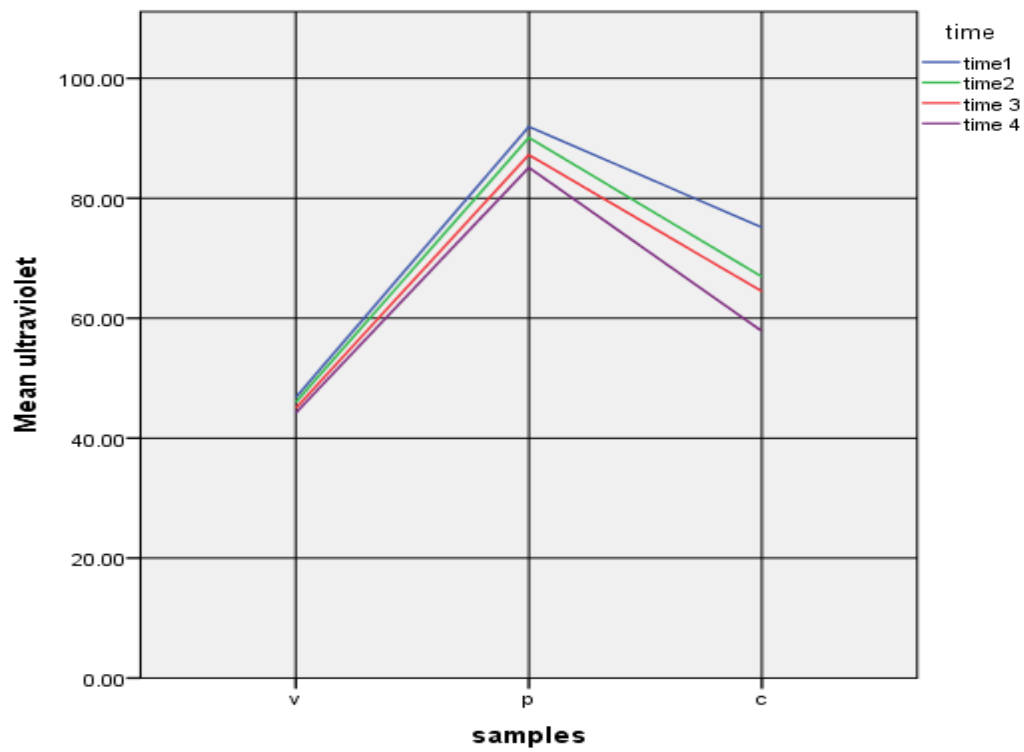
Fig (3-35) Effect of UV radiation on the UPFwith the change of exposure time (sateen design)

Table (3-9) tear properties of fabric (weft and warp direction)

Samples	samples	Weft	Warp
VP	1	3.869	0.411
VT	2	7.340	9.940
VS	3	4.039	4.549
PP	4	4.425	4.795
PT	5	8.820	17.390
PS	6	8.130	9.770
CP	7	3.250	1.543
CT	8	6.740	4.776
CS	9	5.280	4.202

Table (3-9) shows the breaking force values in weft and warp direction of the samples and the values are drawn in figures (3-36) and (3-37) .The plain design got the lowest tear value while twill design got the highest value in all samples because of the increase of intersections.

Loose open structure or long floats in the fabric construction allows increase in thread density, thus more threads present as bundles and the tearing strength value increased in sateen and twill than plain.

Figures from (3-38) to (3-40) showed that polyester got the highest tear value and cotton got the lowest .In all samples the tear strength value decreased after exposing to UV through all periods of time .
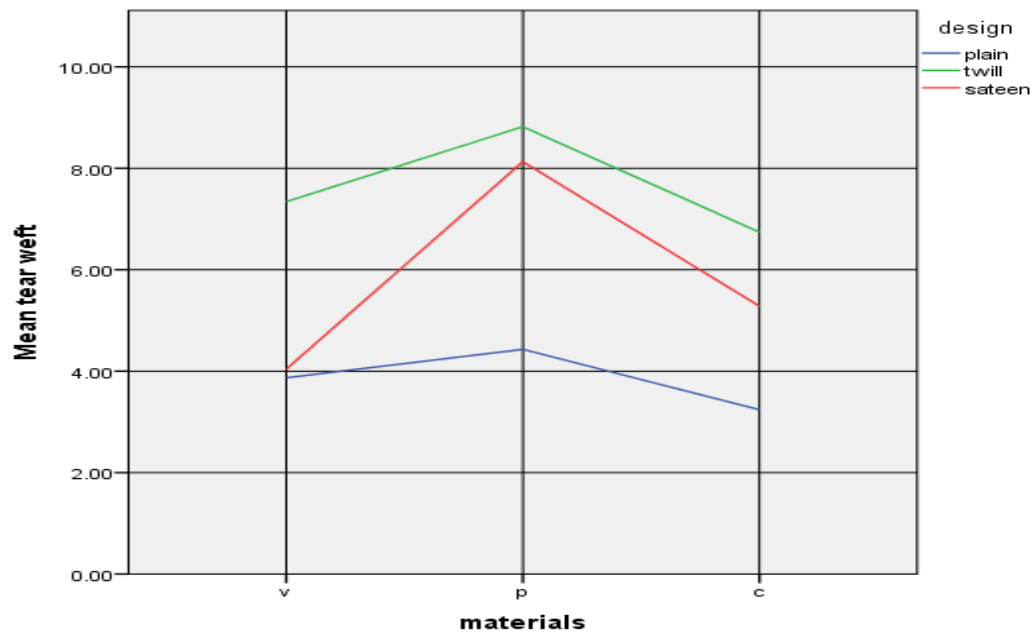
Fig (3-36) the variation of tear in weft direction of the woven fabrics with the materials of samples
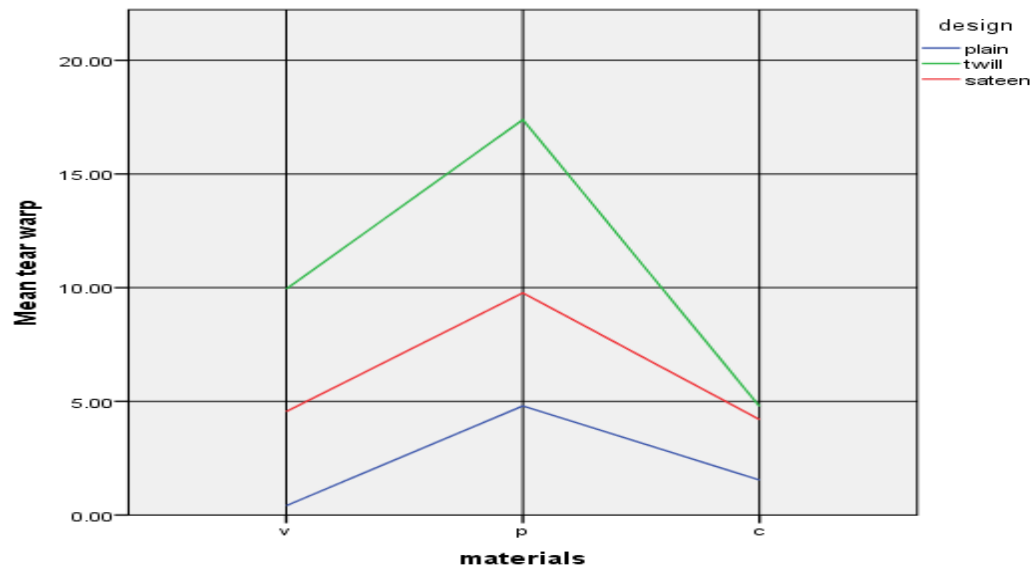
Fig (3-37) the variation of tear in warp direction of the woven fabrics with the materials of samples
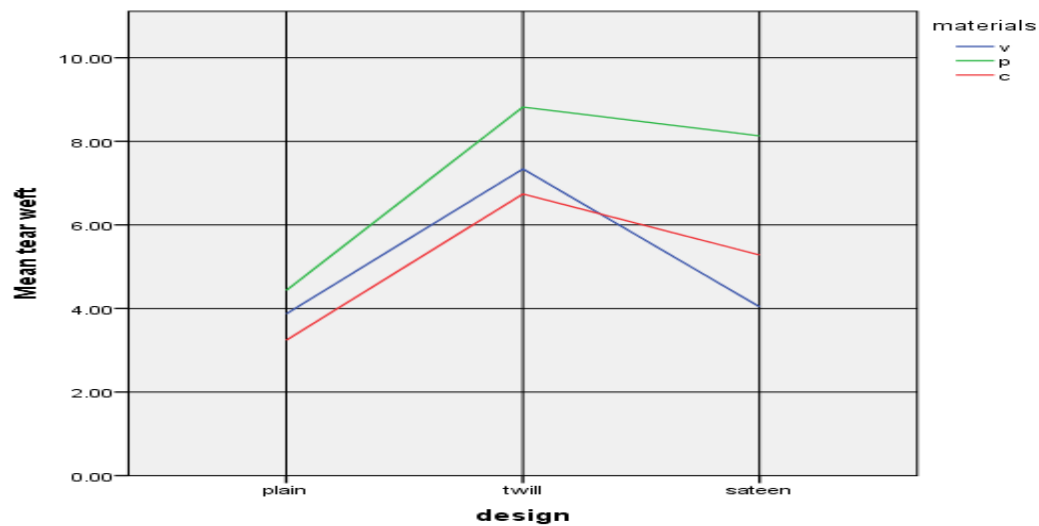
Fig (3-38) the variation of tear in weft direction of the woven fabrics with the design of samples
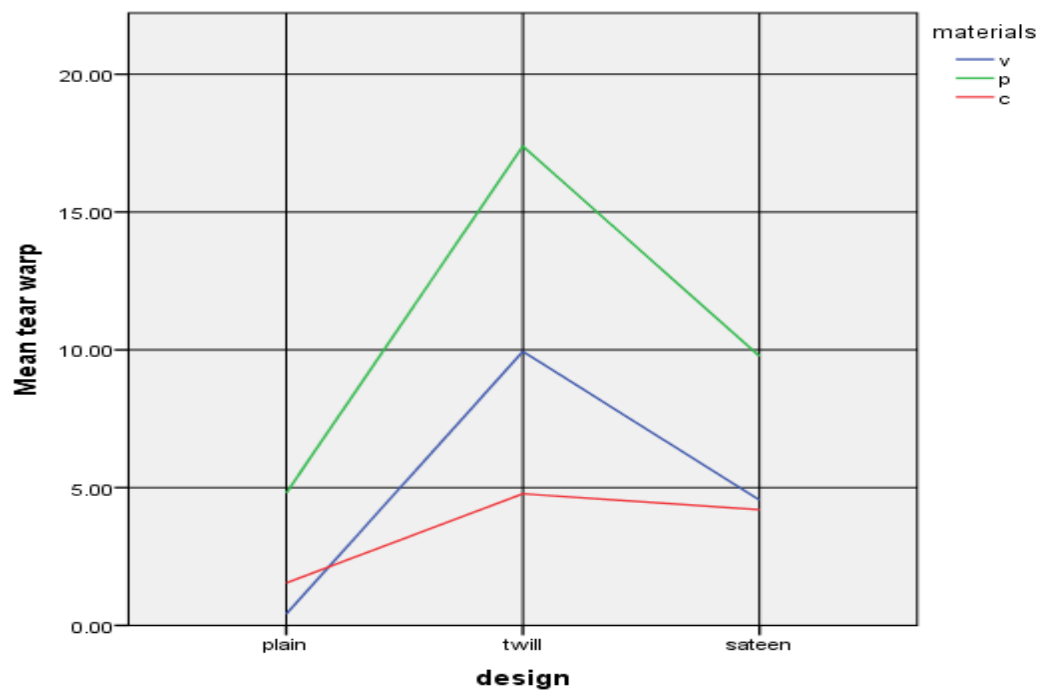
Fig (3-39) the variation of tear in warp direction of the woven fabrics with the design of samples
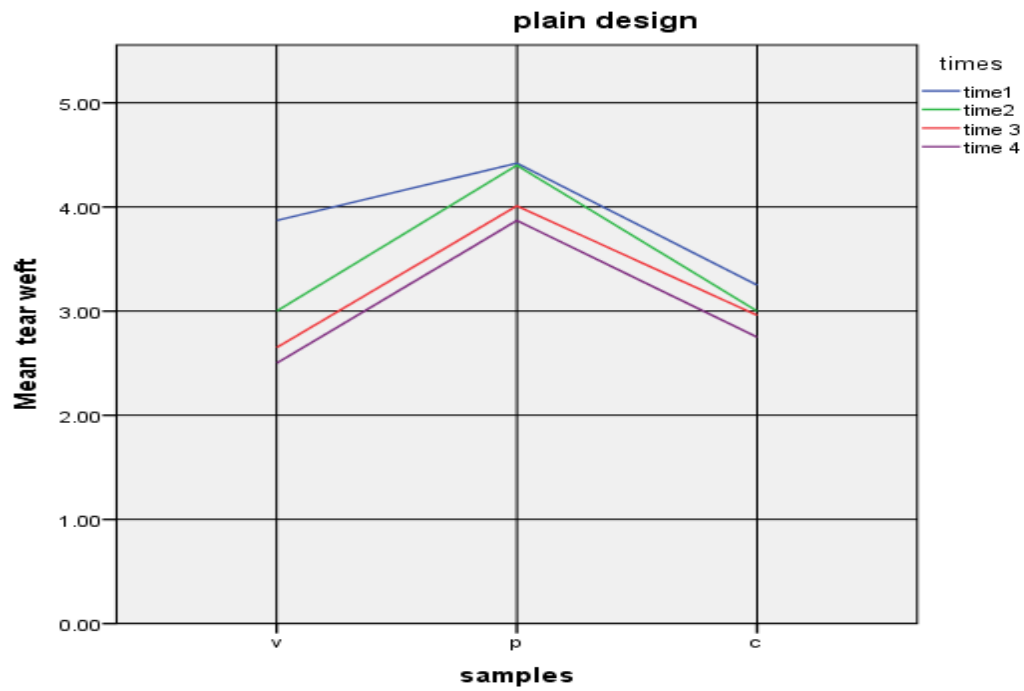
plain design

fig () Deterioration in tear strength is plotted as a function of exposure time

plain design

fig () Deterioration in tear strength is plotted as a function of exposure time

plain 2/2
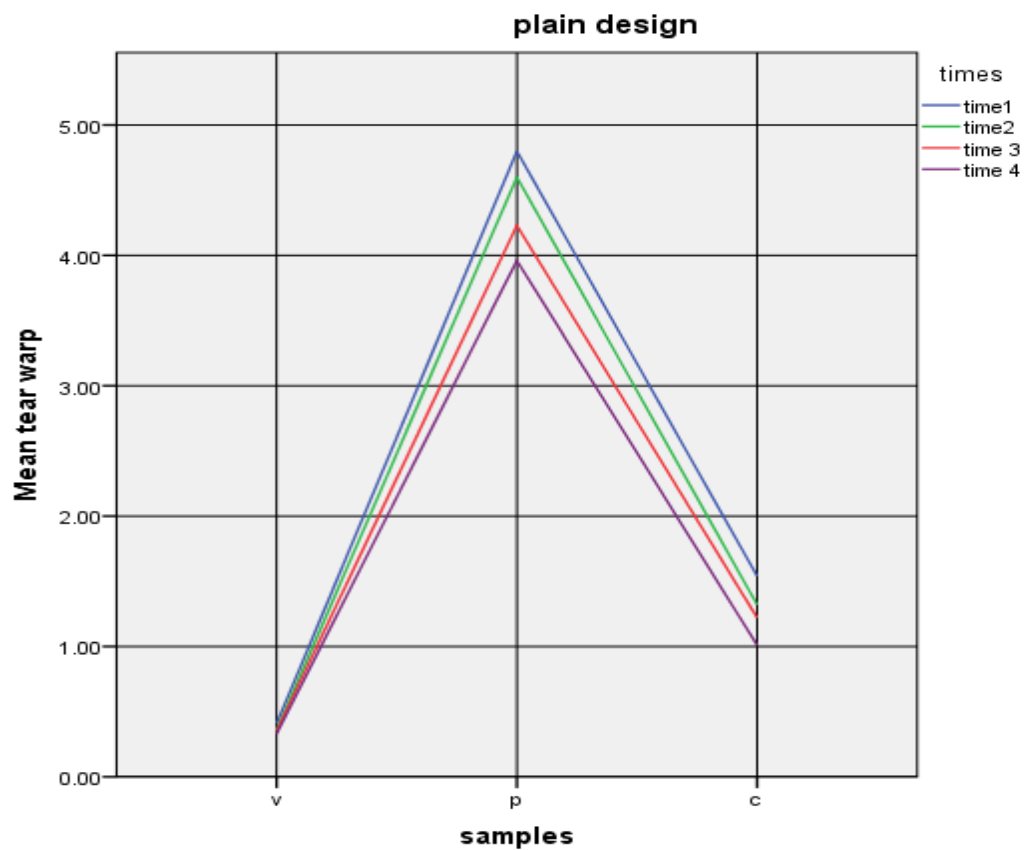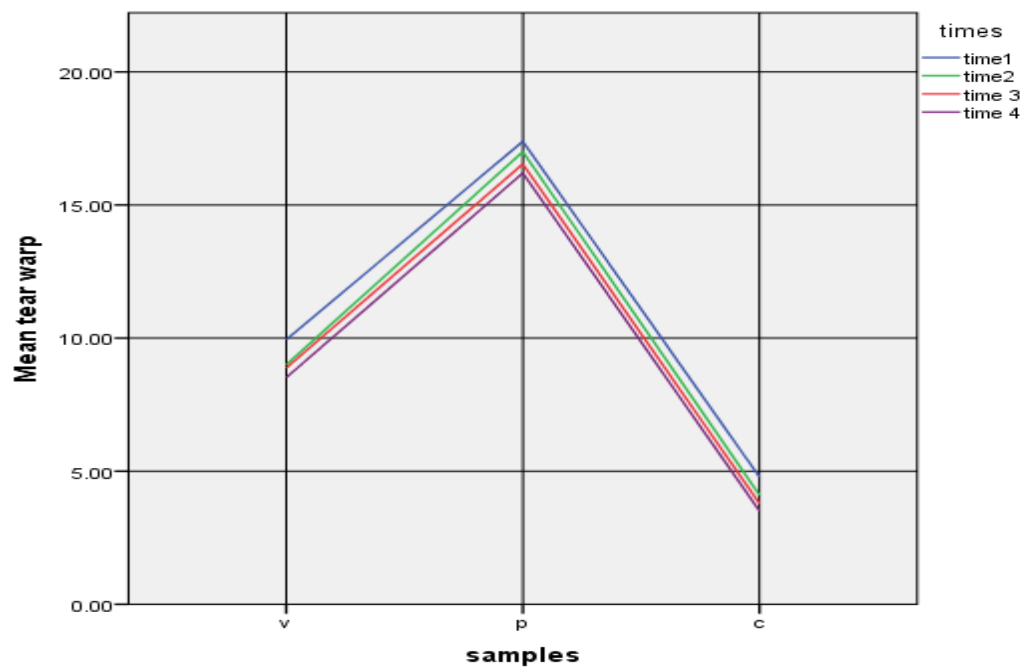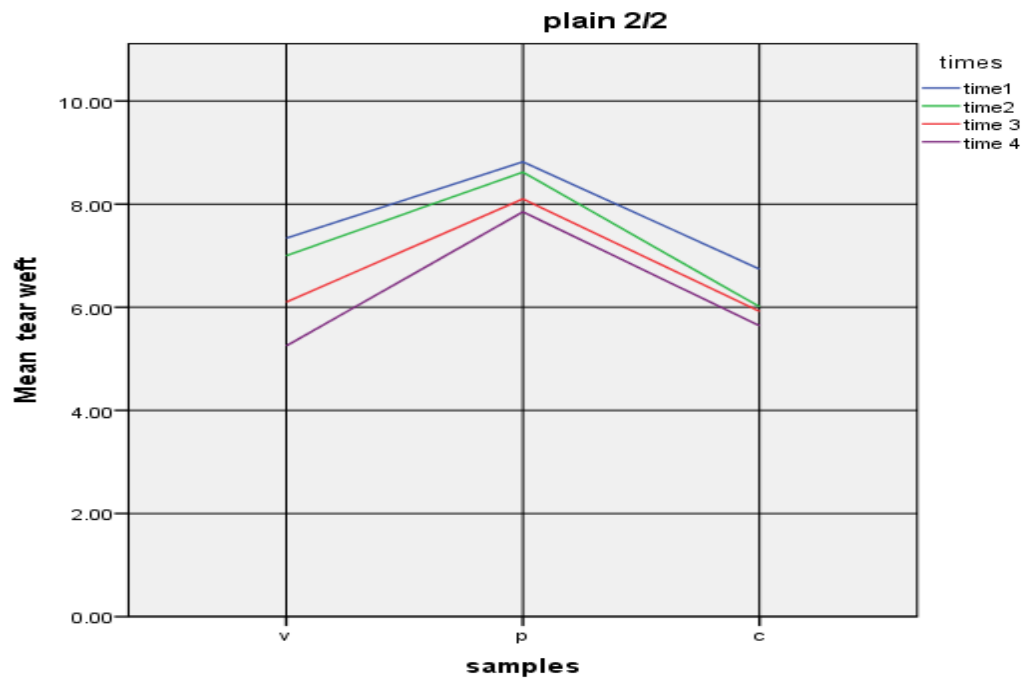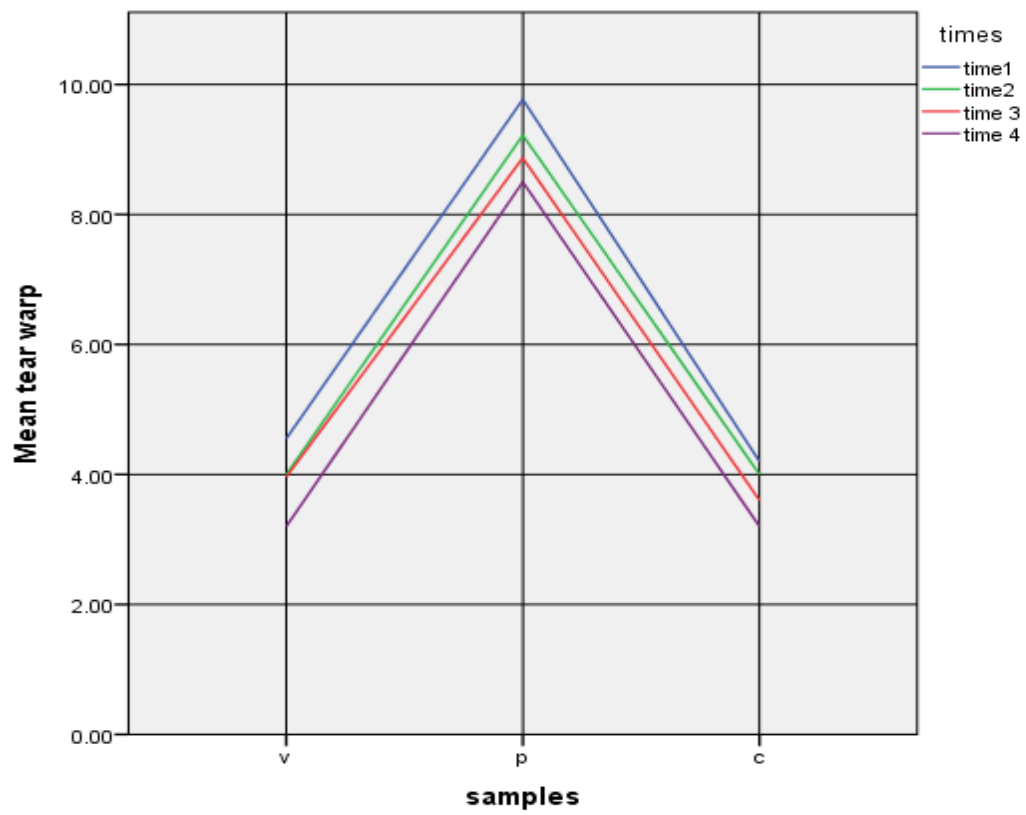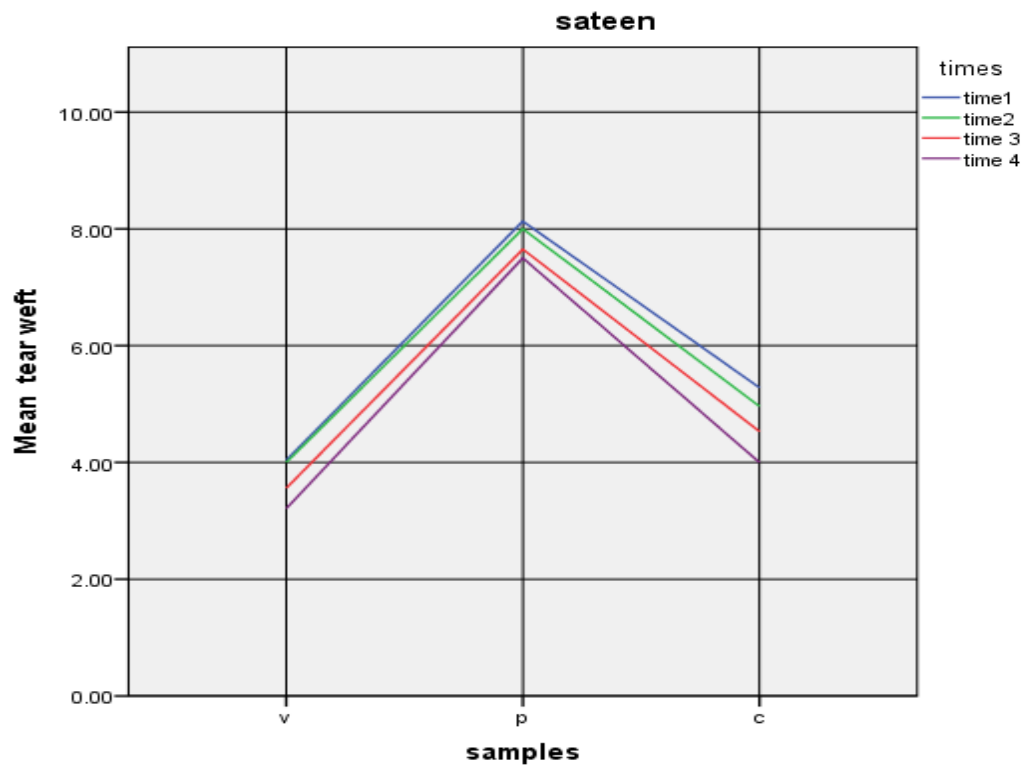
Fig (3-40) Deterioration in tear strength is plotted as a function of exposure time

FT-IR

Ultraviolet ray degradation occurs when energy from UV rays breaks the bonds within the polymer structure. Photons with wavelengths longer than the critical wavelengths for any bond making up the molecular chains will have no effect on the chemical structure, therefore causing no degradation.

A polymer is a long-chain molecule formed when individual units, called monomers, are linked together. A spectral match is based on peak intensity (size) and frequency (wavelength) associated with specific groups of atoms that make up the compounds.

Fourier Transform Infrared Spectroscopy was used to investigate the structural changes that occur during the different developmental stages.

The prominent change which shows that the material has degraded can be seen by the spectra in the wave length range 500-4000 cm^{-1}.there is a decrease in the intensities of the spectrum after hours has been noticed. Lead to a parallel split in its constituent particles series. It represents that the initial functional groups that were present has been attacked by microorganisms, degraded and they have converted them into new biomass.

The spectra of cellulose show decrease of bands particularly which means that the samples are degraded

The FT-IR spectra of polyester fibers show the structure of fibers. The sharp peak represents the presence of ester in the material which is the characteristic functional group of polyester.
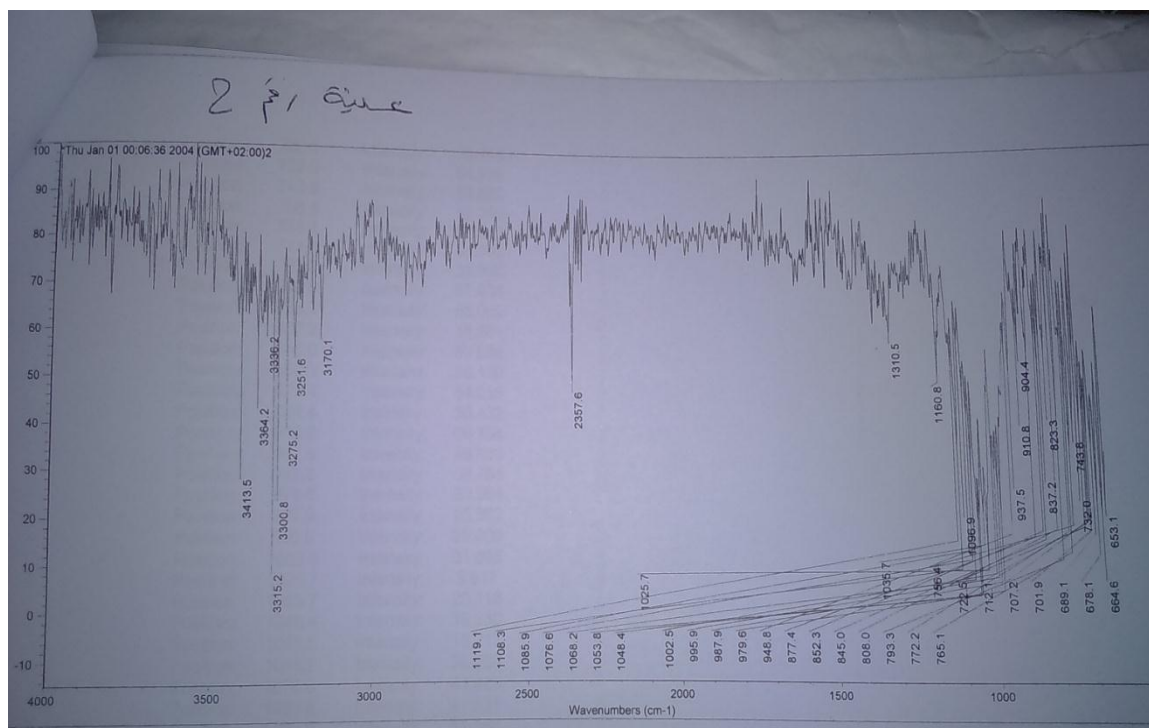
3-1 Characterization of Nanodiamonds Based Coating on Textile Fabrics

It is important to note that, in this study, there were nine different textile fabrics but after screening their properties viscose (V), polyester (P) and cotton(C) have been selected to reflect all of them in the treatment and investigation of their performance. This is due to the similarity of their properties .The morphology of treated textile fabrics with coating layer was investigated using microscopic techniques. When coating layer was applied to fabric surface, the ultrasonication was in dispersion on fabrics surface.

3-2 Using Binder and Acetone only

After using binder and acetone; Breaking force and elongation of textile fabrics (strip method) are tested .The results are shown below on table (3-9) for each material.

Table (3-10) the breaking force and elongation before treatment (with binder and acetone only)

Samples	Elongation %	Maximum force (kgf)
VP1	4.359	58.9
PP1	17.260	140.5
CP1	4.348	58.0

3-3 Processing Using Nanotechnology (After Treatment with Nanodiamond Material)

After using Nanodiamond (40, 80 and 100mg); Breaking force and elongation of textile fabrics (strip method) are tested .The results are shown below on tables (3-10),(3-11) and (3-12) and drawn in figures(3-41),(3-42) and (3-43) as shown for each material.

Table (3-11) the effect of adding nano (40mg) to fabrics samples on the properties of the breaking force and elongation

Samples	Elongation %	Maximum force (kgf)
VP1-N1	4.080	48.45
PP1-N1	13.600	137.50
CP1-N1	3.972	48.85

Table (3-12) the effect of adding nano (80mg) to fabrics samples on the properties of the breaking force and elongation

Samples	Elongation %	Maximum force (kgf)
VP1-N2	4.405	59.2
PP1-N2	16.060	127.6
CP1-N2	4.395	53.9

Table (3-13) the effect of adding nano (100mg) to fabrics samples on the properties of the breaking force and elongation

Samples	Elongation %	Maximum force (kgf)
VP1-N3	3.995	63.0
PP1-N3	14.950	132.8
CP1-N3	9.930	97.3
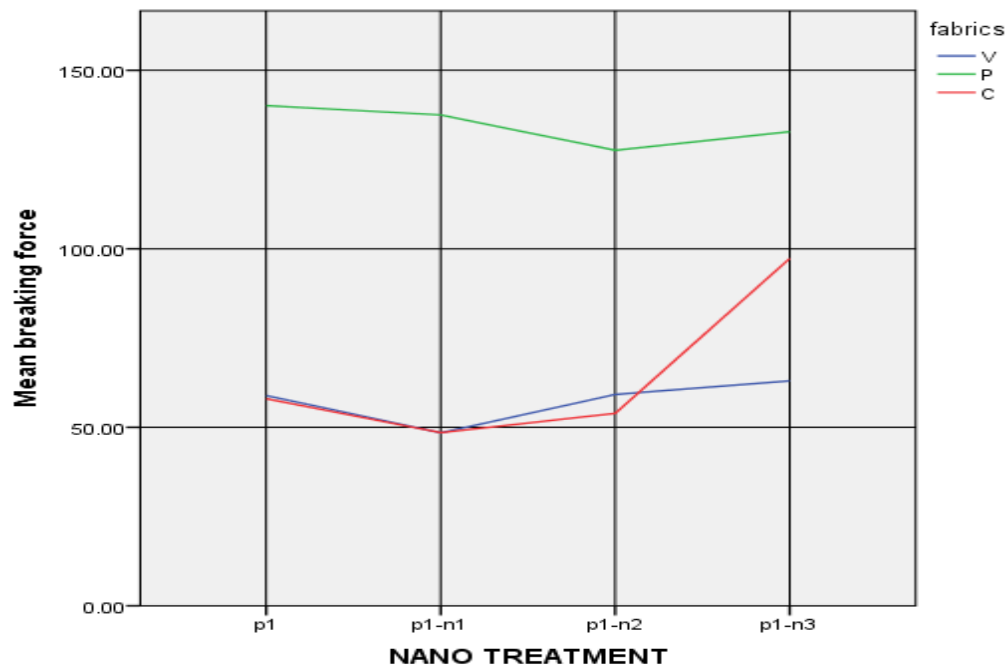
Fig (3-41) the effect of adding nano diamond to fabrics samples on the properties of the breaking force.
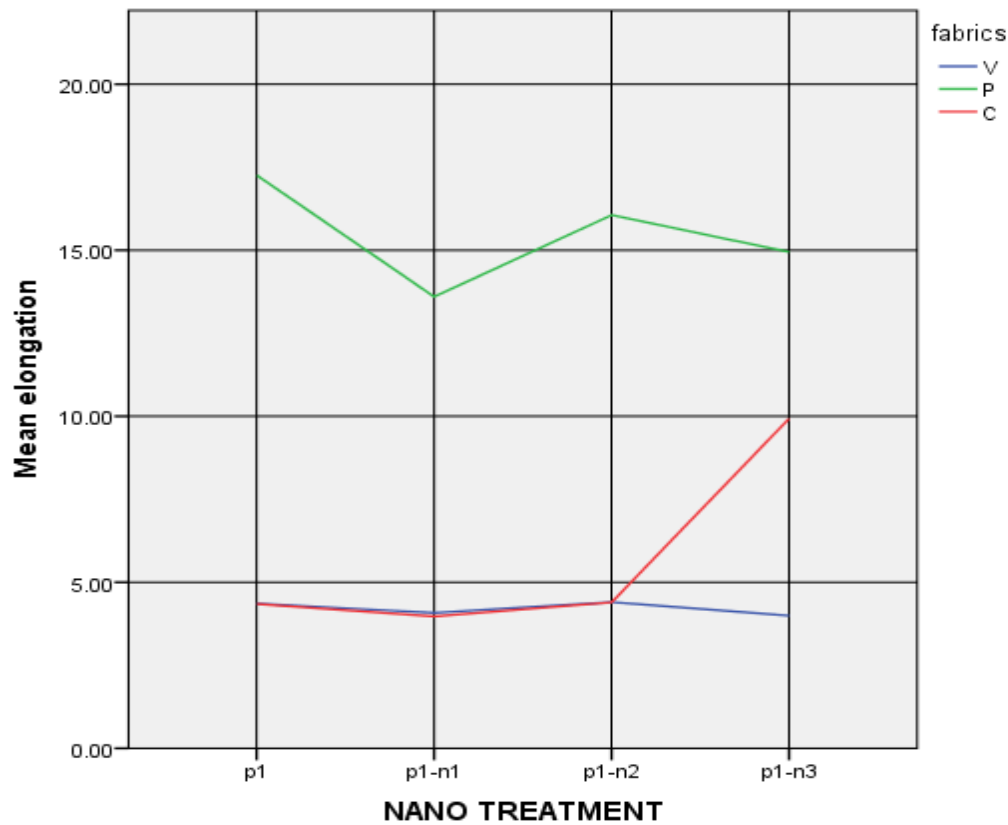
Fig (3-42) the effect of adding nano diamond to fabrics samples on the elongation

3-4 After Ultrasonication Time (1.5and 2hour)

Ultrasonic assembly is accomplished by converting high frequency electrical energy into high frequency mechanical motion. That mechanical motion, along with applied force, creates frictional heat, form a molecular bond between the parts

Table (3-14) the breaking force and elongation after treating with nanodiamond and using ultrasonication time (1.5hour (T1) and 2.5hour (T2))

Samples	Elongation %	Maximum force (kgf)
VP1-N2-T1	18.15	111.7
VP1-N2-T2	17.68	114.9
PP1-N1-T1	16.44	141.1
PP1-N1-T2	15.20	144.6
CP1-N3-T1	5.32	39.1
CP1-N3-T2	4.45	39.64
CP1-N4-T1	4.30	52.4
CP1-N4-T2	11.83	121.3

The breaking force and elongation are measured after treating cotton with 80mg ND, polyester with 40 mg ND and cotton 100 mg and 120 mg ND with the use ultrasonication time and results are tabulated in table (3-13).

Table (3-15) Mass per Unit Area (Weight) of Fabric used before and after treated by nanodiamond by different weight(40,80 and 100mg)

Samples	Weight before/g	Weight after/g
VP1-N1	8.2610	8.6586
VP1-N2	8.2512	8.6228
VP1-N3	7.8506	8.0476
PP1-N1	8.5442	9.0717
PP1-N2	8.6978	9.2568
PP1-N3	8.7207	9.0096
CP1-N1	8.4718	8.7548
CP1-N2	8.0371	8.6601
CP1-N3	7.8891	8.4066

Table (3-16) Mass per Unit Area (Weight) of Fabric after ultrasonication time (1.5and 2hours)

Samples	Weight/g
VP1-N2-T1	9.3148
VP1-N2-T2	9.1212
PP1-N1-T1	9.7260
PP1-N1-T2	9.2433
CP1-N4-T1	9.3650
CP1-N4-T2	8.8136
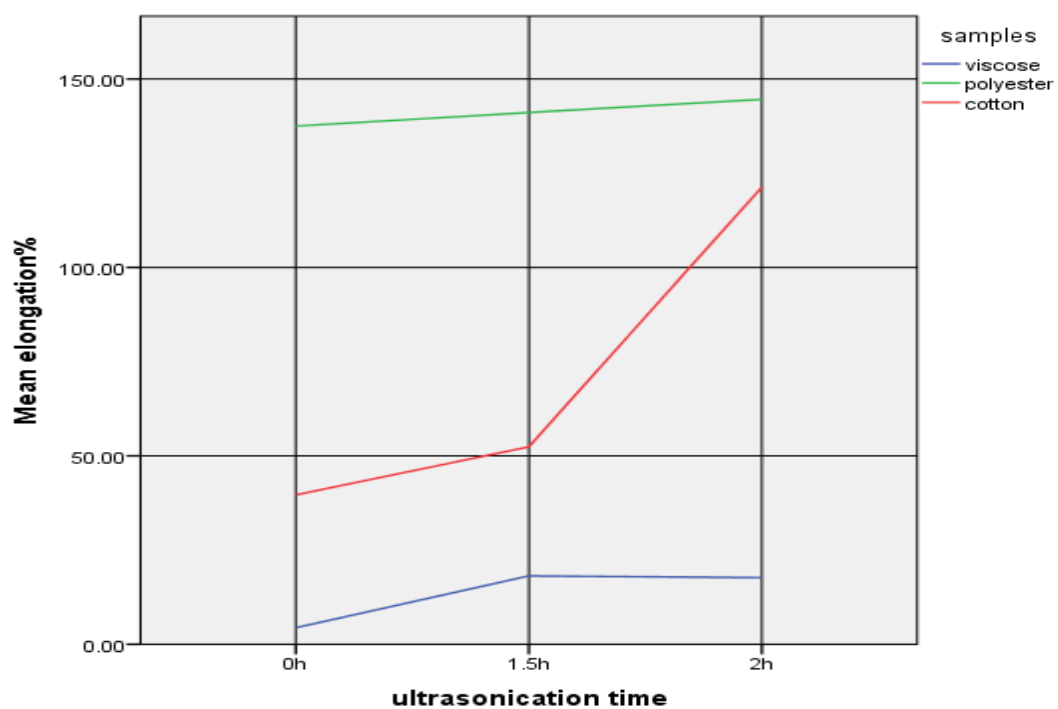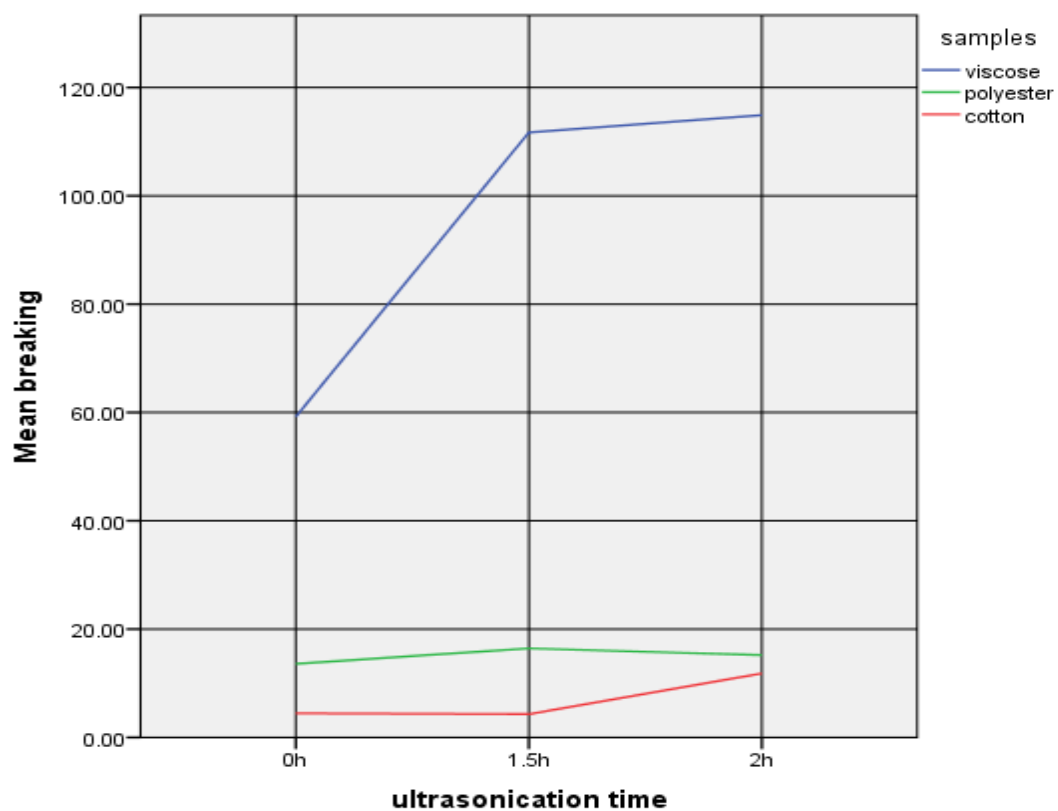
Fig (3-43) the effect of ultrasonication on the properties on fabrics

The breaking force and elongation properties of treated and untreated textile fabrics were investigated , all cotton fabrics, polyester and viscose showed an increase in the breaking force after using binder and acetone only .Tables (3-9 ,3-10,3-11 and 3-12) showed gradual increase in the breaking force after being treated with nanodiamond (ND) as shown and drawn in Fig (3-41) and (3-42).

The breaking force of virgin viscose was 52 and increased to 58.9 when treated with binder and when NDs incorporated the breaking force was firstly decreased, but when mass NDs was added, the breaking force reached 63.When the ultrasonication time increased to 2 hours the breaking force was significantly increased and achieved 114.9 kgf. There is an increase in the elongation which achieved 17.7%.as shown on table (3-13).

Table (3-17) Ultraviolet protection factor (UPF)

Samples	UPF	UV-B	UV-A
VP1	50.79	1.54	5.16
VP1-N1	64.00	1.20	4.19
VP1-N2	107.06	0.72	2.56
VP1-N3	100.66	0.83	2.26
VP1-N1-T1	82.37	0.93	3.35
VP1-N1-T2	90.63	0.84	3.17
PP1	70.09	0.98	5.73
PP1-N1	135.02	0.48	3.26
PP1-N2	126.46	0.54	5.30
PP1-N3	136.76	0.51	2.85
PP1-N1-T1	99.21	0.69	4.11
PP1-N1-T2	115.87	0.59	3.63
CP1	49.17	1.64	4.97
CP1-N1	63.10	1.26	3.82
CP1-N2	56.39	1.50	3.61
CP1-N3	142.52	0.55	1.87
CP1-N1-T1	126.65	0.67	1.63
CP1-N1-T2	216.37	0.40	0.94

The UPF untreated and treated textiles were evaluated. The effect of developed coating layer on absorption of harmful ultraviolet rays and increasing UPF was studied and results are tabulated on table (3-16) .From this table it was shown that the UPF values of untreated viscose and when treated with binder only were 43and 51 respectively .When nano diamonds were Incorporated in the coating layer, the UPF values increased to 64,107 and 101 for viscose, polyester and cotton respectively.

The UPF values increased with the increase of NDs. When ultrasonication time increased to 2 hours the UPF values were significantly enhanced recording 91 for viscose, 116 for polyester and 216 for cotton as shown in Fig (3-44)
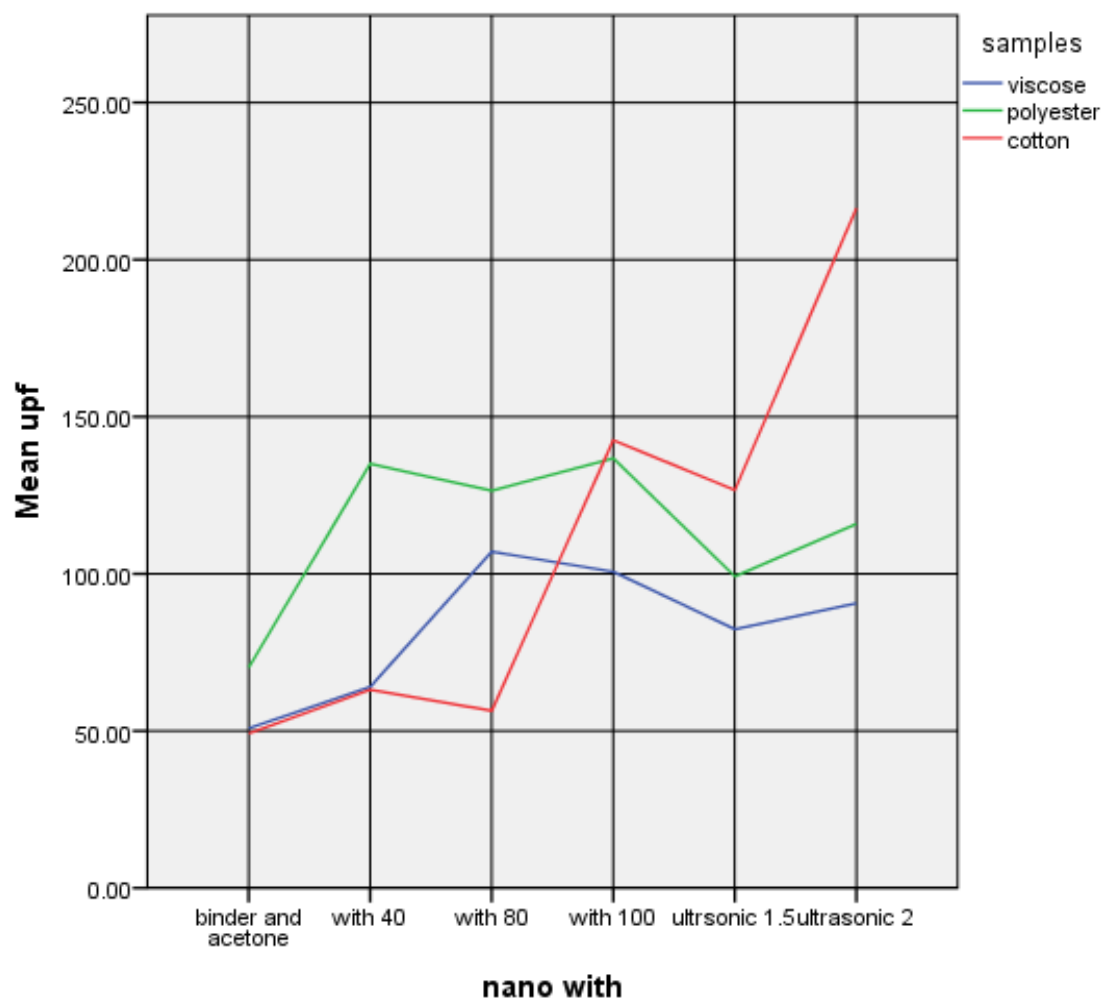
Fig (3-44) the effect of the nano and ultrasonic to the textile fabrics and UPF

The morphology of treated textile fabrics with coating layer was investigated using microscopic techniques. Fig.2a represents the SEM image of blank C which reflects the smooth surface of fibers. However, when coating layer coated the fiber surface of C1it showed rough surface as shown in Fig.2b. This was clearly shown at high magnification when the dispersion of NDs coated with binder was indicated by arrows on fiber surface. Interestingly, when ultrasonication time was increased to 2h the coating layer has completely wrapped the C fiber surface as shown in Fig.2d of C5-1 composite. Also, high magnification showed the NDs coated with binder layer on C fibers as shown in (Fig.2e). This ensures the importance of ultrasonication in dispersion of NDs in B-NDs dispersion.
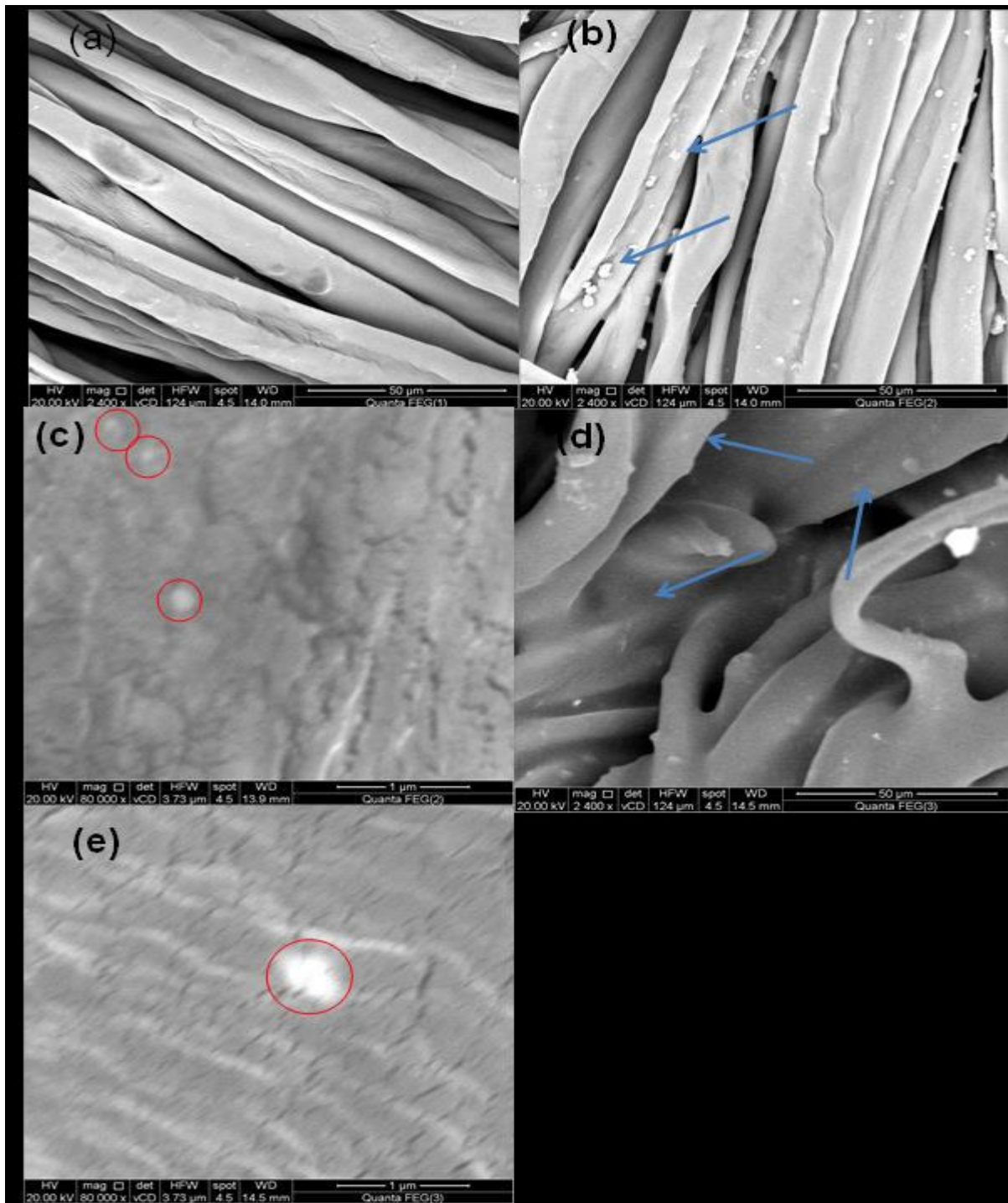
Fig (3-45_) SEM images of blank C (a) c1 (b) and C1 at high magnification (c)
C5-1 (d) and C5-1 at high magnification (e).

Conclusion

Nanotechnology overcomes the limitations of applying conventional methods to impart certain properties to textile materials.   .
UV radiation causes degradation of textile materials, due to excitations in some parts of the polymer molecule and a gradual loss of integrity. Exposure to UV radiation leads to diminishing properties of fabrics and a decrease in the ultraviolet protection of the fabric. All cotton fabrics, polyester and viscose showed a continuous gradual increase in the air permeability with the time of exposure to UV rays. The Plain design of the polyester fabrics showed the lowest value of air permeability. There is a decrease in the degree of stiffness of all fabrics after exposure to uv at warp and weft direction .All the samples showed a decrease in breaking force after exposure to UV.

The nanodimond coating layer has effectively absorbed the harmful UV rays and enhanced breaking force of treated textile fabrics. The mass loading of nanodimond and ultrsonication time played significant role in UV protection and breaking force properties.

Novel nanodiamond based composites were developed for textile fibers coating. The developed composite coat on textile surface served as a smart coating. The ultraviolet protection factor of the treated textile fabrics has significantly enhanced achieving more than 3 fold (300%) increase compared to the untreated fabrics.
 The breaking force properties of the treated fabrics have significantly improved by the nanodiamond coating layer.

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%Reflectance

Thu Jan 01 02:22:23 2004 (GMT+02:00)4

Wavenumbers (cm-1)

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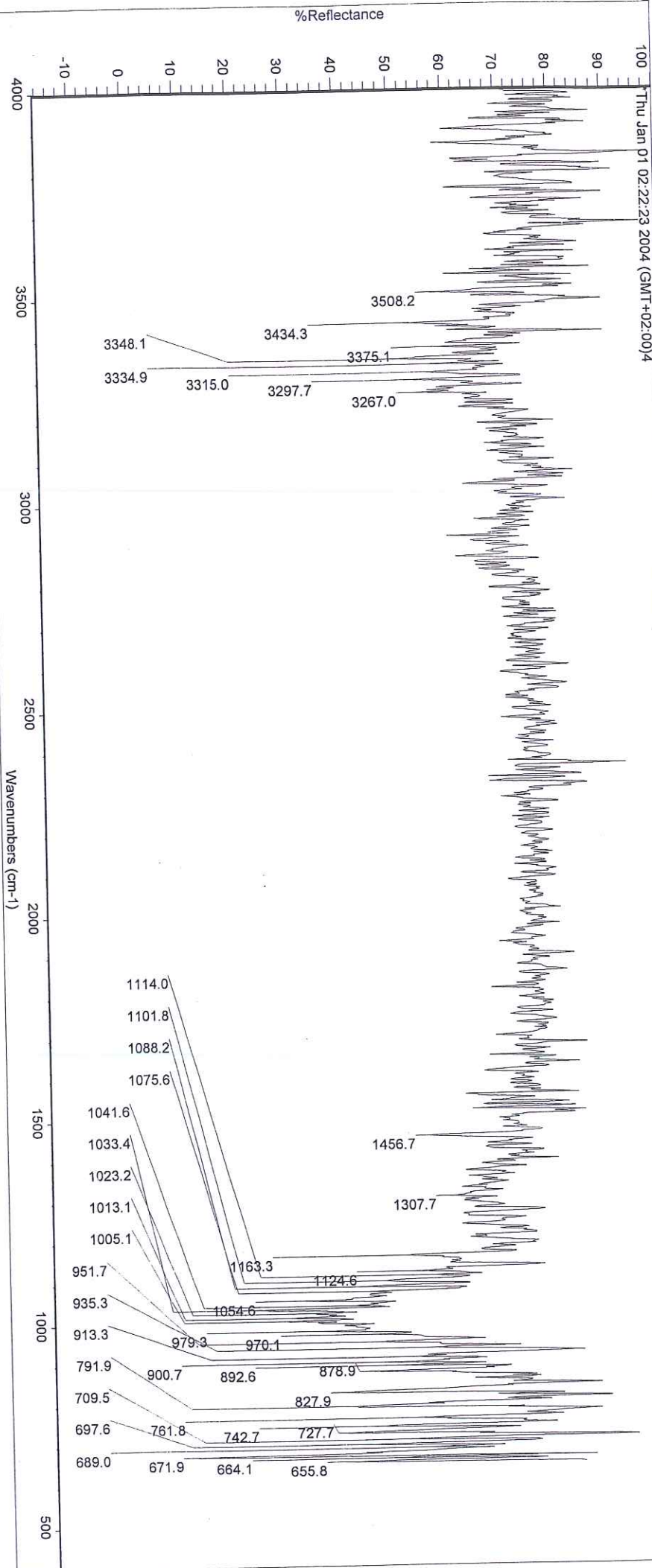
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Position:	664.1	Intensity:	45.463
Position:	671.9	Intensity:	7.108
Position:	689.0	Intensity:	53.805
Position:	697.6	Intensity:	39.521
Position:	709.5	Intensity:	46.956
Position:	709.5	Intensity:	37.158

Position:	Intensity:
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791.9	39.481
827.9	37.107
878.9	41.665
892.6	46.270
900.7	45.301
913.3	51.466
935.3	55.271
951.7	44.760
970.1	44.242
979.3	34.337
1005.1	26.509
1013.1	27.210
1023.2	31.610
1033.4	21.058
1041.6	38.091
1054.6	30.823
1075.6	41.334
1088.2	39.746
1101.8	45.694
1114.0	54.345
1124.6	52.375
1163.3	49.610
1307.7	57.987
1456.7	54.059
3267.0	53.392
3297.7	51.525
3315.0	56.035
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3508.2	57.305

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%Reflectance

Wavenumbers (cm-1)
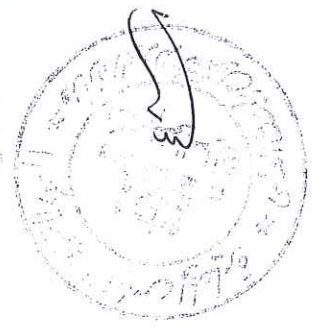
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Position: 947.7   Intensity: 55.215
Position: 970.2   Intensity: 40.875
Position: 989.8   Intensity: 27.639
Position: 1001.2   Intensity: 26.904
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Position: 1016.8   Intensity: 12.156
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Position: 1111.1   Intensity: 30.358
Position: 1122.4   Intensity: 54.577
Position: 1141.0   Intensity: 52.968
Position: 1150.5   Intensity: 54.168
Position: 1164.5   Intensity: 51.623
Position: 1205.0   Intensity: 56.110
Position: 3226.2   Intensity: 55.612
Position: 3258.7   Intensity: 51.361
Position: 3317.4   Intensity: 50.840
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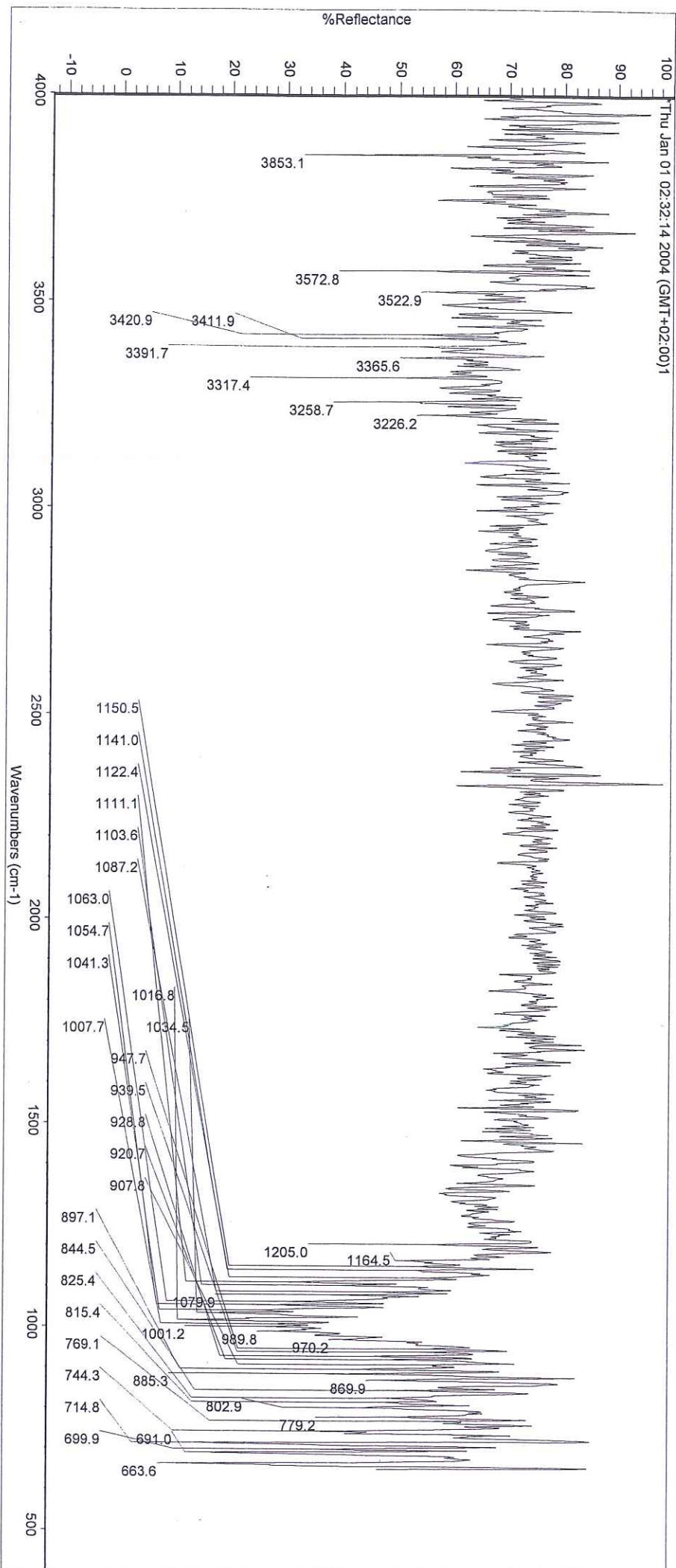Thu Jan 01 02:28:46 2004 (GMT+02:00)2

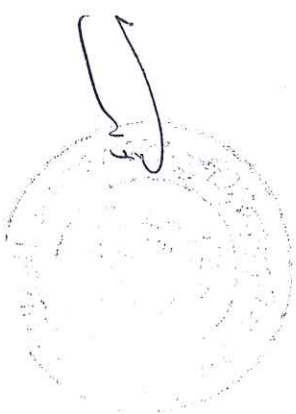%Reflectance

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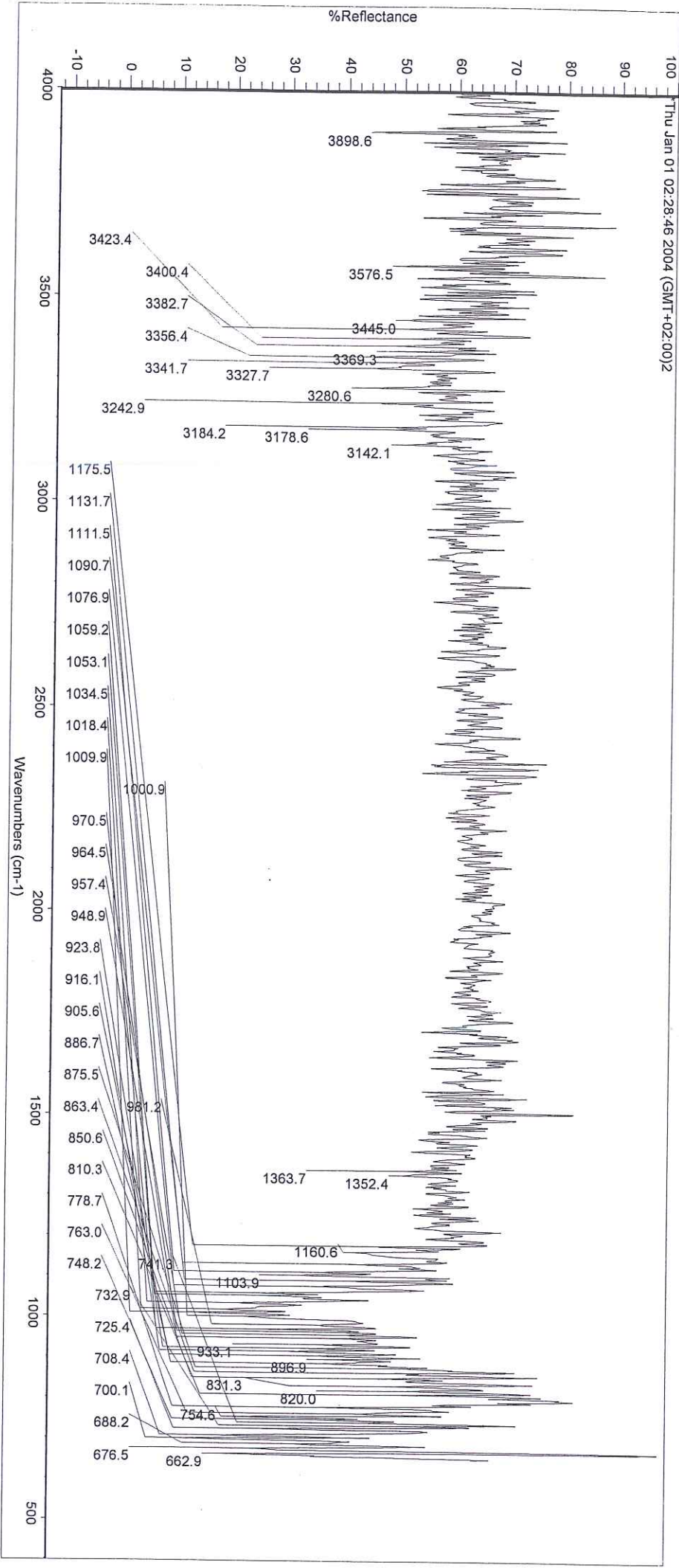Absolute threshold: 51.932
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	Position:	700.1	Intensity:	9.989
	Position:	708.4	Intensity:	17.980
	Position:	725.4	Intensity:	26.382
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Wavenumbers (cm-1)

Peak labels on spectrum:
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Position	Intensity
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754.6	19.803
763.0	44.671
778.7	35.388
810.3	51.387
820.0	51.578
831.3	47.862
850.6	46.853
863.4	49.273
875.5	50.290
886.7	37.570
896.9	37.192
905.6	35.739
916.1	31.262
923.8	32.859
933.1	35.906
948.9	38.829
957.4	40.782
964.5	38.877
970.5	27.006
981.2	36.642
1000.9	23.192
1009.9	11.660
1018.4	18.980
1034.5	21.588
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1059.2	25.366
1076.9	36.669
1090.7	41.108
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1111.5	36.126
1131.7	41.633
1160.6	42.287
1175.5	45.334
1352.4	51.375
1363.7	51.820
3142.1	50.129
3178.6	48.612
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3242.9	44.549
3280.6	43.218
3327.7	44.329

Position: 3341.7   Intensity: 49.457
Position: 3356.4   Intensity: 44.600
Position: 3369.3   Intensity: 48.142
Position: 3382.7   Intensity: 48.190
Position: 3400.4   Intensity: 51.126
Position: 3423.4   Intensity: 50.843
Position: 3445.0   Intensity: 50.952
Position: 3576.5   Intensity: 48.258
Position: 3898.6   Intensity: 45.007

%Reflectance

Thu Jan 01 02:25:43 2004 (GMT+02:00)3

3753.2

3388.6
3300.2
3293.6
3281.0
3375.9
3354.4
3338.8
3454.7
3264.8
3242.0
3233.7

1402.1

1153.9
1120.2
1108.9
1097.3
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1046.0
1033.6
1021.7
1009.3
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979.6
839.0
825.1
991.4
820.2
941.7
812.2
931.9
772.7
918.3
766.5
911.2
757.4
905.4
740.4
703.1
693.8
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Wavenumbers (cm-1)
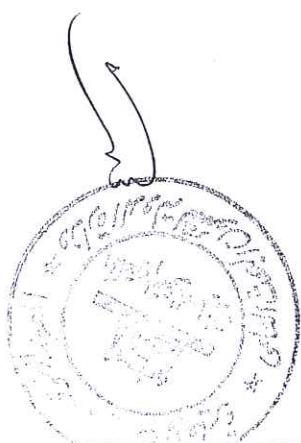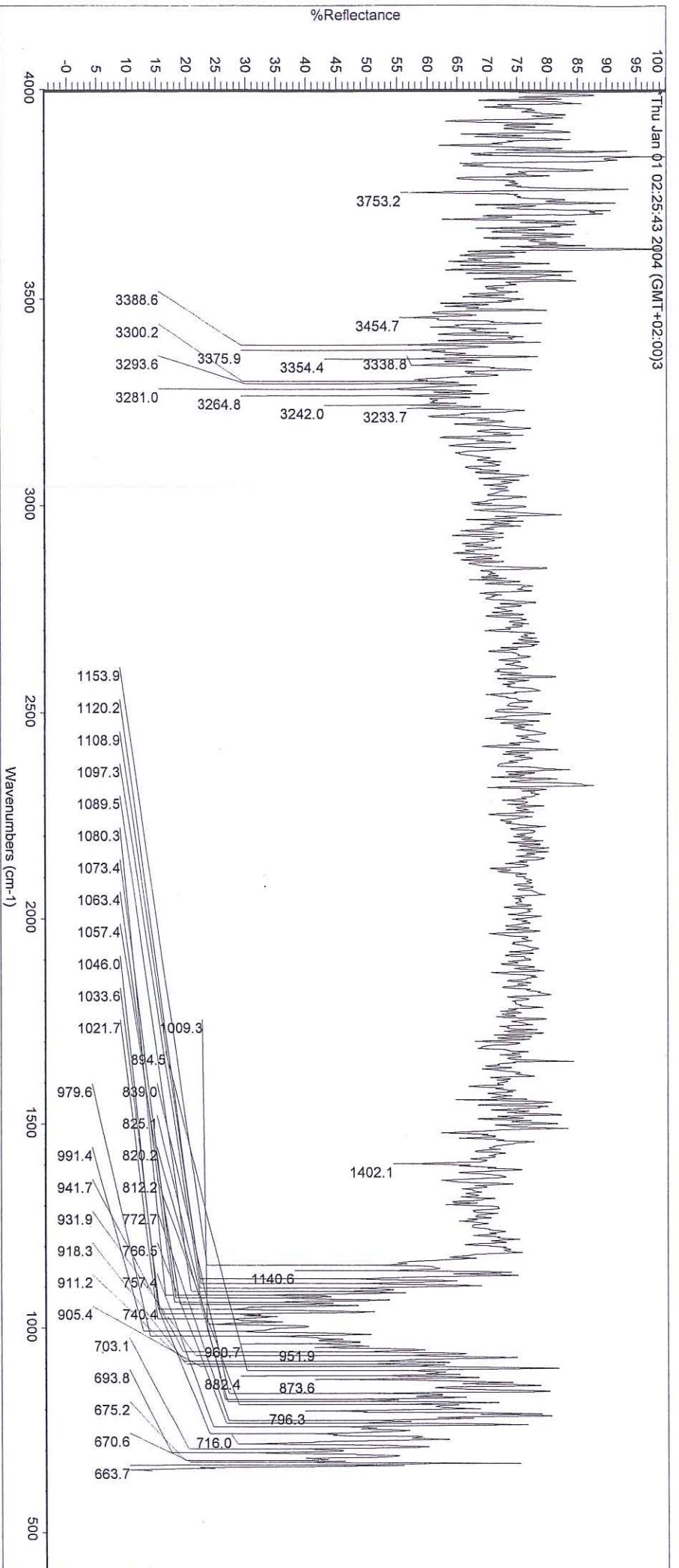
Thu Jan 01 02:52:30 2004 (GMT+02:00)

FIND PEAKS:

Spectrum: *Thu Jan 01 02:25:43 2004 (GMT+02:00)3
Region: 4000.0   400.0
Absolute threshold: 59.464
Sensitivity: 42
Peak list:

	Position:	663.7	Intensity:	44.831
	Position:	670.6	Intensity:	40.295
	Position:	675.2	Intensity:	37.443
	Position:	693.8	Intensity:	30.384
	Position:	703.1	Intensity:	38.256
	Position:	716.0	Intensity:	29.027
	Position:	740.4	Intensity:	40.933
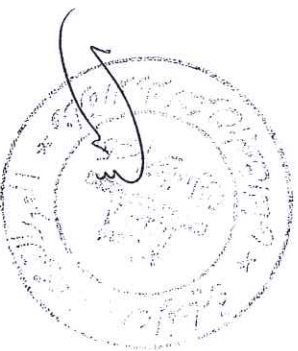
Position:	757.4	Intensity:	41.804
Position:	766.5	Intensity:	47.297
Position:	772.7	Intensity:	49.850
Position:	796.3	Intensity:	41.639
Position:	812.2	Intensity:	55.148
Position:	820.2	Intensity:	48.677
Position:	825.1	Intensity:	48.361
Position:	839.0	Intensity:	49.996
Position:	873.6	Intensity:	43.493
Position:	882.4	Intensity:	52.231
Position:	894.5	Intensity:	56.311
Position:	905.4	Intensity:	56.833
Position:	911.2	Intensity:	49.856
Position:	918.3	Intensity:	49.711
Position:	931.9	Intensity:	55.347
Position:	941.7	Intensity:	49.160
Position:	951.9	Intensity:	42.718
Position:	960.7	Intensity:	42.045
Position:	979.6	Intensity:	32.932
Position:	991.4	Intensity:	29.541
Position:	1009.3	Intensity:	24.309
Position:	1021.7	Intensity:	27.027
Position:	1033.6	Intensity:	28.488
Position:	1046.0	Intensity:	26.862
Position:	1057.4	Intensity:	37.444
Position:	1063.4	Intensity:	34.923
Position:	1073.4	Intensity:	35.591
Position:	1080.3	Intensity:	30.493
Position:	1089.5	Intensity:	43.278
Position:	1097.3	Intensity:	48.034
Position:	1108.9	Intensity:	49.159
Position:	1120.2	Intensity:	48.249
Position:	1140.6	Intensity:	52.922
Position:	1153.9	Intensity:	51.919
Position:	1402.1	Intensity:	56.368
Position:	3233.7	Intensity:	58.506
Position:	3242.0	Intensity:	56.994
Position:	3264.8	Intensity:	54.853
Position:	3281.0	Intensity:	53.633
Position:	3293.6	Intensity:	58.538
Position:	3300.2	Intensity:	57.000
Position:	3338.8	Intensity:	58.680
Position:	3354.4	Intensity:	57.550

Position: 3375.9   Intensity: 58.655
Position: 3388.6   Intensity: 56.253
Position: 3454.7   Intensity: 57.396
Position: 3753.2   Intensity: 57.872

Thu Jan 01 02:53:10 2004 (GMT+02:00)
FIND PEAKS:

Spectrum: *Thu Jan 01 02:19:03 2004 (GMT+02:00)5
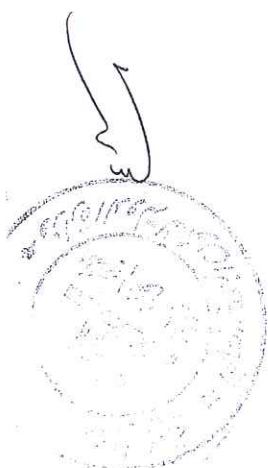Region: 4000.0   400.0
Absolute threshold: 58.177
Sensitivity: 42
Peak list:

Position:	655.3	Intensity:	36.342
Position:	663.4	Intensity:	9.994
Position:	669.6	Intensity:	29.566
Position:	677.1	Intensity:	49.885
Position:	686.6	Intensity:	25.532
Position:	694.7	Intensity:	28.964
Position:	705.1	Intensity:	31.210

Position:	Intensity:
720.9	19.418
730.7	21.959
746.9	48.931
754.4	47.335
763.2	35.438
780.5	36.802
791.2	28.878
809.5	46.098
825.7	36.867
839.3	42.834
849.4	47.990
873.1	37.906
881.1	52.302
893.2	35.262
917.1	49.370
935.4	34.871
946.9	38.958
955.3	41.437
981.8	22.058
989.0	19.065
1000.8	21.351
1008.5	11.608
1020.1	13.297
1025.6	20.159
1034.0	13.374
1047.7	12.452
1057.8	25.651
1064.4	23.107
1074.5	34.586
1082.4	26.900
1092.1	43.130
1099.0	32.522
1104.2	31.511
1117.8	30.372
1156.5	41.835
1189.2	57.006
1210.9	56.213
1227.0	52.902
1240.4	46.019
1253.5	43.594
1268.3	43.305
1287.1	49.955
1314.1	55.312

Position:	1340.1	Intensity:	51.256
Position:	1398.9	Intensity:	56.602
Position:	1415.0	Intensity:	50.585
Position:	1456.0	Intensity:	53.475
Position:	1471.1	Intensity:	57.362
Position:	1615.9	Intensity:	55.773
Position:	1653.3	Intensity:	55.287
Position:	1679.3	Intensity:	55.855
Position:	1702.8	Intensity:	45.070
Position:	1723.8	Intensity:	54.953
Position:	2366.4	Intensity:	55.760
Position:	3307.6	Intensity:	48.845
Position:	3355.9	Intensity:	56.900
Position:	3611.7	Intensity:	56.054
Position:	3732.1	Intensity:	57.024

%Reflectance

*Thu Jan 01 02:15:50 2004 (GMT+02:00)6

Wavenumbers (cm-1)
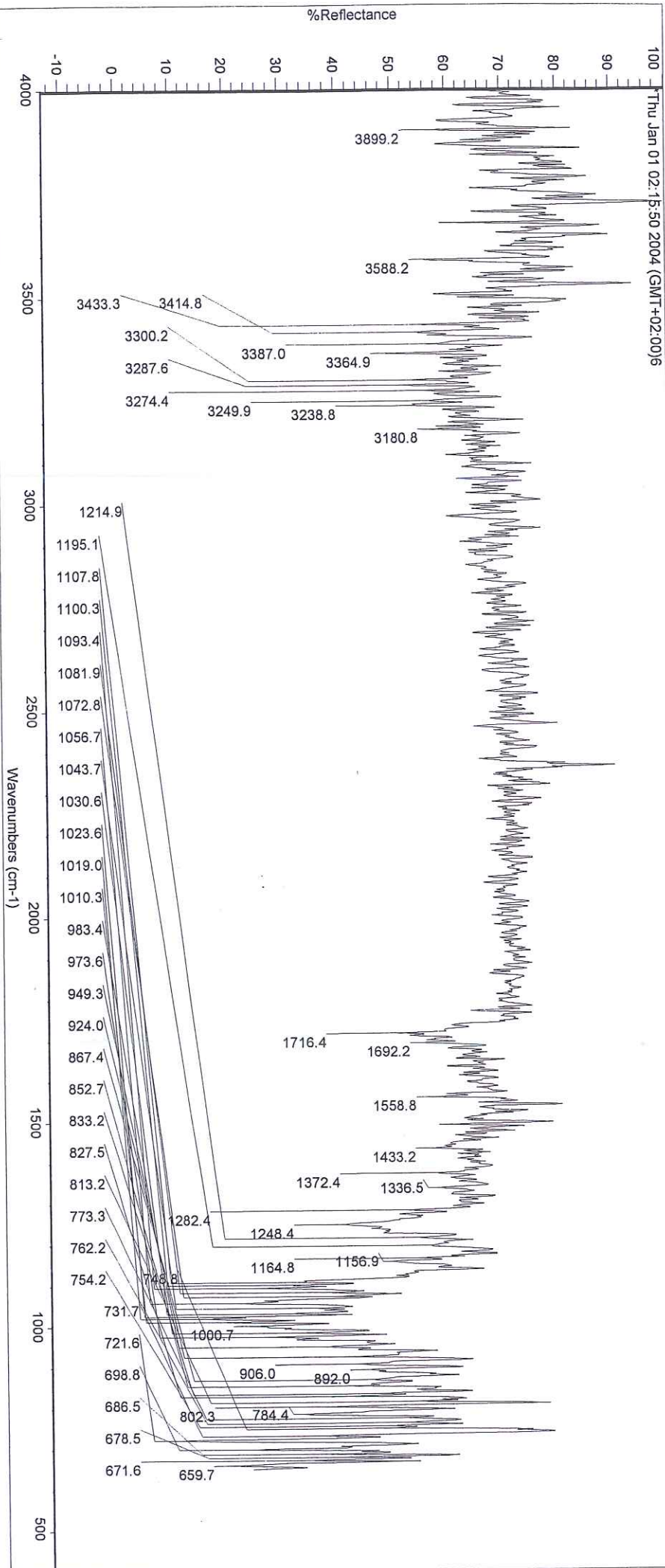
Thu Jan 01 02:54:25 2004 (GMT+02:00)

FIND PEAKS:
Spectrum: *Thu Jan 01 02:15:50 2004 (GMT+02:00)6
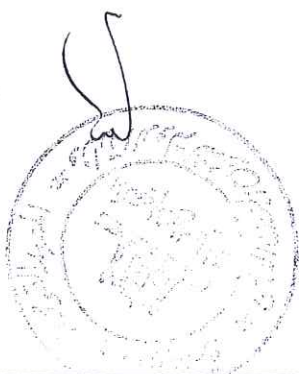Region: 4000.0   400.0
Absolute threshold: 57.219
Sensitivity: 42
Peak list:

	Position:		Intensity:
Position:	659.7	Intensity:	18.890
Position:	671.6	Intensity:	34.092
Position:	678.5	Intensity:	38.448
Position:	686.5	Intensity:	36.562
Position:	698.8	Intensity:	23.061
Position:	721.6	Intensity:	9.823
Position:	731.7	Intensity:	36.309

Peaks labeled on spectrum:
3899.2, 3588.2, 3433.3, 3414.8, 3387.0, 3364.9, 3300.2, 3287.6, 3274.4, 3249.9, 3238.8, 3180.8, 1716.4, 1692.2, 1558.8, 1433.2, 1372.4, 1336.5, 1282.4, 1248.4, 1214.9, 1195.1, 1164.8, 1156.9, 1107.8, 1100.3, 1093.4, 1081.9, 1072.8, 1056.7, 1043.7, 1030.6, 1023.6, 1019.0, 1010.3, 1000.7, 983.4, 973.6, 949.3, 924.0, 906.0, 892.0, 867.4, 852.7, 833.2, 827.5, 813.2, 802.3, 784.4, 773.3, 762.2, 754.2, 748.8, 731.7, 721.6, 698.8, 686.5, 678.5, 671.6, 659.7

Position:	Intensity:
748.8	45.850
754.2	47.377
762.2	51.558
773.3	51.350
784.4	32.117
802.3	36.180
813.2	53.398
827.5	36.692
833.2	44.487
852.7	40.469
867.4	45.063
892.0	43.939
906.0	41.584
924.0	39.206
949.3	36.521
973.6	25.552
983.4	32.306
1000.7	22.664
1010.3	18.697
1019.0	14.766
1023.6	17.143
1030.6	29.052
1043.7	34.902
1056.7	21.214
1072.8	39.121
1081.9	37.190
1093.4	23.695
1100.3	29.536
1107.8	31.834
1156.9	48.665
1164.8	52.861
1195.1	55.833
1214.9	53.792
1248.4	40.290
1282.4	51.029
1336.5	57.085
1372.4	56.700
1433.2	55.513
1558.8	55.437
1692.2	54.297
1716.4	49.326
3180.8	56.724
3238.8	53.073

Position: 3249.9 Intensity: 56.767
Position: 3274.4 Intensity: 54.725
Position: 3287.6 Intensity: 51.719
Position: 3300.2 Intensity: 53.215
Position: 3364.9 Intensity: 48.405
Position: 3387.0 Intensity: 56.267
Position: 3414.8 Intensity: 54.430
Position: 3433.3 Intensity: 55.165
Position: 3588.2 Intensity: 54.489
Position: 3899.2 Intensity: 53.935

%Reflectance
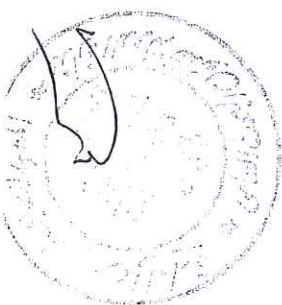
Thu Jan 01 02:12:33 2004 (GMT+02:00)7

Wavenumbers (cm-1)

Peak positions labeled on spectrum:
3902.8, 3629.4, 3577.3, 3543.5, 3520.2, 3439.4, 3412.1, 3403.3, 3395.7, 3382.5, 3372.5, 3347.2, 3333.9, 3317.9, 3305.5, 3296.1, 3281.6, 3265.8, 3205.2, 3171.7, 3151.2, 1683.8, 1234.0, 1167.1, 1156.7, 1149.9, 1105.6, 1088.1, 1073.9, 1059.0, 1053.0, 1045.0, 1033.2, 1009.6, 1004.5, 988.6, 979.3, 972.3, 959.1, 938.9, 929.8, 918.7, 909.2, 902.3, 889.0, 877.3, 866.1, 838.6, 829.7, 812.4, 806.0, 799.1, 789.8, 774.9, 761.6, 753.8, 748.1, 724.9, 715.2, 698.2, 683.5, 669.3, 661.7, 653.3

	Position:		Intensity:
	653.3		9.321
	661.7		23.679
	669.3		33.262
	683.5		32.747
	698.2		45.151
	715.2		36.302
	724.9		36.439

Position:	Intensity:
748.1	47.300
753.8	42.415
761.6	52.257
774.9	40.196
789.8	53.762
799.1	53.494
806.0	49.939
812.4	40.495
829.7	50.923
838.6	44.879
866.1	30.049
877.3	50.504
889.0	59.035
902.3	46.611
909.2	57.230
918.7	45.718
929.8	49.526
938.9	39.591
959.1	45.823
972.3	35.872
979.3	27.858
988.6	21.650
1004.5	24.887
1009.6	25.217
1033.2	11.000
1045.0	16.384
1053.0	25.657
1059.0	23.112
1073.9	41.085
1088.1	34.850
1105.6	26.131
1149.9	52.553
1156.7	56.091
1167.1	57.980
1234.0	58.425
1683.8	57.224
3151.2	59.154
3171.7	58.389
3205.2	55.852
3265.8	54.096
3281.6	54.237
3296.1	57.906
3305.5	59.398

Position: 3317.9   Intensity: 57.912
Position: 3333.9   Intensity: 55.640
Position: 3347.2   Intensity: 58.299
Position: 3372.5   Intensity: 53.584
Position: 3382.5   Intensity: 50.732
Position: 3395.7   Intensity: 56.443
Position: 3403.3   Intensity: 59.197
Position: 3412.1   Intensity: 57.406
Position: 3439.4   Intensity: 55.328
Position: 3520.2   Intensity: 55.519
Position: 3543.5   Intensity: 57.190
Position: 3577.3   Intensity: 59.376
Position: 3629.4   Intensity: 59.512
Position: 3902.8   Intensity: 51.965

%Reflectance

Thu Jan 01 02:09:06 2004 (GMT+02:00)8

Spectrum peak labels (upper region):
3971.2, 3689.3, 3674.0, 3629.6, 3577.5, 3567.0, 3479.4, 3456.9, 3427.7, 3391.0, 3324.9, 3278.7, 3234.5

1508.0, 1452.4, 1260.4

1166.4, 1159.7, 1149.8, 1130.4, 1124.0, 1113.1, 1106.9, 1098.1, 1079.8, 1069.5, 1036.8, 1022.5, 1011.3, 1001.9, 993.0, 984.4, 947.7, 940.9, 929.0, 920.2, 904.7, 883.5, 869.3, 841.4, 816.4, 796.3, 788.5, 777.0, 768.2, 757.5, 741.7, 724.0, 716.8, 707.6, 685.6, 669.2, 661.0

Wavenumbers (cm-1)

X-axis: 4000, 3500, 3000, 2500, 2000, 1500, 1000, 500
Y-axis: 100, 90, 80, 70, 60, 50, 40, 30, 20, 10, 0, -10

Thu Jan 01 02:54:57 2004 (GMT+02:00)

FIND PEAKS:

Spectrum: *Thu Jan 01 02:09:06 2004 (GMT+02:00)8
Region: 4000.0   400.0
Absolute threshold: 61.813
Sensitivity: 42
Peak list:

	Position:		Intensity:
Position:	661.0	Intensity:	32.712
Position:	669.2	Intensity:	48.586
Position:	685.6	Intensity:	40.533
Position:	707.6	Intensity:	10.519
Position:	716.8	Intensity:	47.761
Position:	724.0	Intensity:	33.261
Position:	741.7	Intensity:	40.083

Position:	Intensity:
757.5	46.147
768.2	51.272
777.0	40.131
788.5	49.663
796.3	38.356
816.4	58.269
841.4	54.479
869.3	55.518
883.5	45.175
904.7	43.827
920.2	48.825
929.0	52.993
940.9	53.714
947.7	54.682
984.4	24.516
993.0	13.701
1001.9	30.981
1011.3	13.026
1022.5	17.889
1036.8	9.328
1069.5	35.958
1079.8	36.122
1098.1	45.432
1106.9	44.695
1113.1	42.148
1124.0	55.896
1130.4	55.901
1149.8	51.002
1159.7	57.731
1166.4	55.644
1260.4	60.922
1452.4	60.580
1508.0	61.298
3234.5	60.514
3278.7	54.278
3324.9	55.304
3391.0	59.978
3427.7	58.382
3456.9	60.553
3479.4	60.133
3567.0	50.153
3577.5	61.270
3629.6	45.733

Position: 3674.0   Intensity: 53.145
Position: 3689.3   Intensity: 61.066
Position: 3971.2   Intensity: 56.553

%Reflectance

Thu Jan 01 00:28:46 2004 (GMT+02:00)9

Wavenumbers (cm-1)

Peak labels (on spectrum):
3962.3
3871.9 3858.2
3732.7
3629.2 3599.6
3559.4 3515.4
3489.5 3453.3
3329.4
3289.5 3263.0
3229.0
3197.9 3149.0
3057.2
2928.1 2918.1
1712.7
1501.0
1407.6
1337.9
1236.3
1095.9
1019.8
922.3
900.9 868.5
749.6 724.1 820.2 813.5 793.1 773.2
706.9
685.0 698.7
677.3 660.1
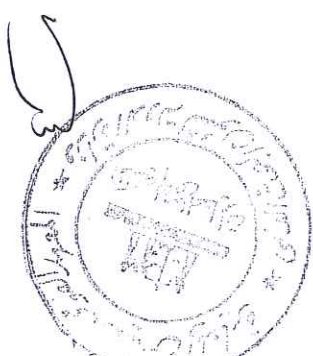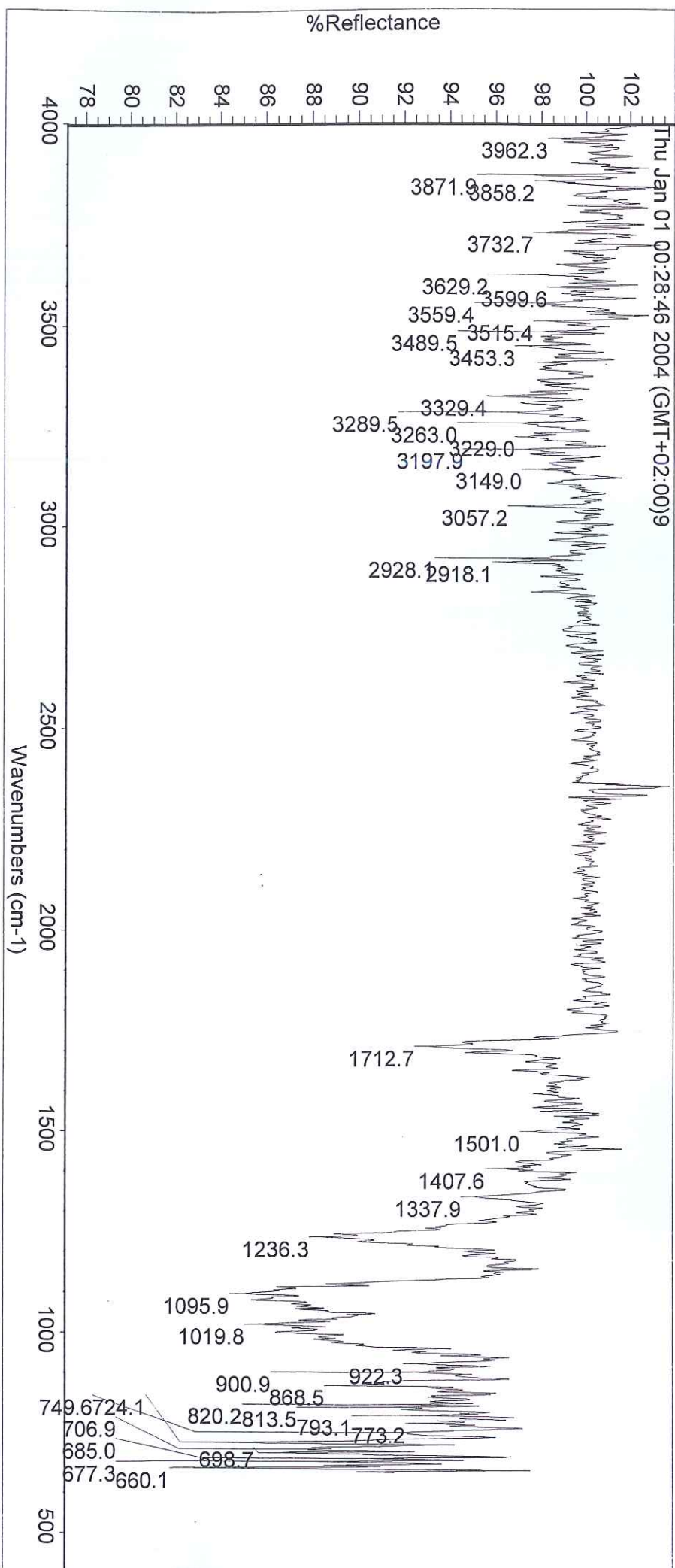
Thu Jan 01 00:13:16 2004 (GMT+02:00)

FIND PEAKS:
Spectrum: Thu Jan 01 00:28:46 2004 (GMT+02:00)9
Region: 4000.0   400.0
Absolute threshold: 98.814
Sensitivity: 26
Peak list:

	Position:		Intensity:	
Position:	660.1	Intensity:	81.874
Position:	677.3	Intensity:	88.769
Position:	685.0	Intensity:	90.541
Position:	698.7	Intensity:	85.861
Position:	706.9	Intensity:	87.731
Position:	724.1	Intensity:	84.889
Position:	749.6	Intensity:	92.026

Position:		Intensity:	
Position:	773.2	Intensity:	92.807
Position:	793.1	Intensity:	92.280
Position:	813.5	Intensity:	91.563
Position:	820.2	Intensity:	92.001
Position:	868.5	Intensity:	88.927
Position:	900.9	Intensity:	92.683
Position:	922.3	Intensity:	92.548
Position:	1019.8	Intensity:	85.661
Position:	1095.9	Intensity:	84.979
Position:	1236.3	Intensity:	88.479
Position:	1337.9	Intensity:	95.123
Position:	1407.6	Intensity:	96.179
Position:	1501.0	Intensity:	97.691
Position:	1712.7	Intensity:	93.092
Position:	2918.1	Intensity:	96.432
Position:	2928.1	Intensity:	96.990
Position:	3057.2	Intensity:	97.087
Position:	3149.0	Intensity:	97.701
Position:	3197.9	Intensity:	97.258
Position:	3229.0	Intensity:	97.393
Position:	3263.0	Intensity:	97.152
Position:	3289.5	Intensity:	96.789
Position:	3329.4	Intensity:	96.063
Position:	3453.3	Intensity:	97.322
Position:	3489.5	Intensity:	97.786
Position:	3515.4	Intensity:	98.198
Position:	3559.4	Intensity:	97.779
Position:	3599.6	Intensity:	98.600
Position:	3629.2	Intensity:	97.697
Position:	3732.7	Intensity:	97.894
Position:	3858.2	Intensity:	98.108
Position:	3871.9	Intensity:	97.536
Position:	3962.3	Intensity:	98.643