

PROPERTIES IMPROVEMENT ON POLYESTER FABRIC USING POLYVINYL ALCOHOL



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ABSTRACT

Polyethylene terephthalate is one of the important synthetic ester polymeric material used in widespread areas. In textile industry, this fibrous material finds use in most of the garment and apparel applications due to its ease of handling, maintenance, and drying and competes with cotton materials. However, due to the maximum hydrophobic behavior, this textile material gives number of issues like accumulation of statics, negligible moisture content, poor comfort and aesthetic characters. Hence, in order to use this polyester material in the general textile industries particularly for garment and apparel productions, it is necessary to increase to some extent of its hydrophilic character by the application of some suitable chemicals like polyvinyl alcohol. In these context, in this work an attempt is made to treat the polyethylene terephthalate fabric with sodium hydroxide followed by polyvinyl alcohol so as to increase the aesthetic properties. The output received after the polyvinyl alcohol treatment on this fabric gives the good results expected for the garment applications.

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Keywords: Polyethylene Terephthalate (Polyester), Polyvinyl Alcohol, Scanning Electron Microscope, Fourier-Transform Infrared Spectroscopy, X-Ray Diffraction

1. INTRODUCTION

Polyethylene terephthalate (PET), commonly called as Polyester is the term used to denote the long-chain polymers chemically composed of at least 85% by weight of an ester and a dihydric alcohol and a terephthalic acid. The reaction of alcohol with carboxylic acid results with the formation of esters. Polyester is a general term in which the work poly- meaning many, and ester, a basic organic chemical compound [AATCC test method 197-2011](#), [AATCC test method 20A-2002](#), [AATCC test method 79-2010](#). Polyester was one of the important and prominent man-made fiber discoveries of the forties and being manufactured for industrial scale since 1947. Polyester fibrous materials are the first choice for the production of apparel and are used in trousers, skirts, shirts, suits, jackets, blouses, home furnishings, hats, bed sheets, blankets, upholstered furniture and computer mouse mats [AATCC test method 20A-2002](#), [Bal, S, & Behera, RC 2006](#), [Barker AF 2004](#). Moreover, industrial polyester fibers, yarns and ropes are used in different reinforcement materials, fabrics for conveyor belts, safety belts, coated fabrics and plastic reinforcements with high-energy absorption aspects.



Polyester fiber is also in the usage as cushioning and insulating material in pillows, comforters and upholstery padding 4,6,7. Polyester fabrics can provide specific advantages over natural fabrics, such as improved wrinkle resistance, durability and high color retention). As a result, polyester fibers are sometimes spun together with natural fibers to produce a cloth with blended properties [Campbell, IM 2000](#), [Dave, J, Kumar, R, & Srivastava, HC 1987](#), [Faterpekar, SA, & Potnis, SP 1981](#)

One of the earliest and most widely accepted method is treatment of PET fabric with sodium hydroxide. It is least expensive method of surface treatment. After alkali treatment the fabric becomes soft and silky to touch, with reduced static charge and soiling behavior [Finch, CA, Polyvinyl alcohol 1973](#), [Gohil, JM, Bhattacharya, A. and Ray, P. 2006](#), [Hearle, JWS 1972](#). The improved performance of alkali treated PET fabric can be attributed to increase in surface roughness of the fiber and polar groups generated as a result of hydrolysis of ester linkage [Gohil, JM, Bhattacharya, A. and Ray, P. 2006](#), [J. Jeyakodi Moses, and Gnanapriya 2016](#), [J. Shao, J. Zheng, J. Liu, C.M. Carr 2005](#). Poly(vinyl alcohol) is a water soluble and biodegradable synthetic polymer. It is a dry solid, and is available in granule and powdered forms. Most of the properties of polyvinyl alcohol depend on the degree of polymerization and the degree of hydrolysis. Degree of hydrolysis refers to the ratio of hydrophilic alcohol group and hydrophobic acetate group. Higher the degree of polymerization, the higher will be the viscosity of solution and adhesive strength [Kimizu, M, Shimb, Y, Abe, T, & Hori, T 2005](#), [Kish, MH, & Nouri, M 1999](#), [Kudlacek, L, Hepnan, M, & Kasparova, Z 1986](#). Accordingly, in this work, an attempt is made to treat the polyester fabric with sodium hydroxide followed by polyvinyl alcohol in different concentrations and to select the optimum values. The output of the work gives convincing results suitable for the polyester fabric in the conventional garment and apparel end use applications.

2. EXPERIMENTAL

2.1. MATERIALS

The 100% plain woven polyester fabric (polyethylene terephthalate) with the specifications such as; yarn count (both warp and weft) – 85, GSM - 68, cover factor – 15.83, ends per inch – 92, picks per inch – 80. The chemicals such as; polyvinyl alcohol, $(C_2H_4O)_n$; degree of polymerization 1700 -1900, sodium hydroxide (NaOH), hydrochloric acid (HCl), acetic acid (CH_3COOH), disperse dye (CI number : 64500) etc. used in this study are in analytical grade.

2.2. METHODS

2.2.1. PRE-TREATMENT OF POLYESTER FABRIC

The 100% raw polyester fabric was desized by immersing in 10g/l (gram per litre) hydrochloric acid solution at ambient temperature for one hour with the material to liquor ratio (MLR) 1:20; in order to remove the added size impurities so as to facilitate the smooth subsequent processes. After desizing the polyester fabric was thoroughly washed and dried [Kulshreshtha, AK, Khan, AH, & Madan, GL 1978](#), [Ledford, WT, & Wasson, JR 1989](#).

2.2.2. TREATMENT OF POLYESTER FABRIC WITH SODIUM HYDROXIDE

The desized polyester fabric was treated with sodium hydroxide of concentration 5%, 10% and 15% (w/v) for 30 minutes at 50°C for imparting swelling and partial hydrolysis in the polyester polymer arrangements [Li, Y, Neoh, K.G, & Kang, ET 2004](#), [Ludewig, H 1964](#).

2.2.3. TREATMENT OF POLYESTER FABRIC WITH POLYVINYL ALCOHOL

The sodium hydroxide treated polyester fabric was subjected with polyvinyl alcohol in alkaline medium (maintained by 1 N NaOH, pH 8.5) with concentration of 3%, 5%, and 10% (w/v) for 30 minutes at 80°C. After this the polyester fabric was dried at 105°C for 30 minutes and cured at 140°C for 120 sec. Then the polyester fabric was thoroughly washed and dried [Namboodri, CGG, & Haith, MS 1968](#), [Namboodri, CGG, & Haith, MS 1968](#).

2.2.4. DYEING OF POLYESTER FABRIC

The polyester fabrics (desized, sodium hydroxide treated, polyvinyl alcohol treated) were dyed with disperse dye of 2% (owm) concentration for two hours at around 95°C and the MLR maintained was 1:20; so as to confirm the effect of alkaline polyvinyl alcohol application. After dyeing the polyester fabric was soaped, washed and dried [Nimchua, T, Eveleigh, DE, Sangwatanaroj, U, & Punnapayak, H 2008](#), [Ohe, T, Yoshimura, Y, & Abe, I 2007](#), [Ohguchi, M, Igeta, K, & Yashumura, T 1980](#).

2.2.5. MEASUREMENT OF PHYSICAL PROPERTIES OF THE POLYESTER FABRIC

The physical properties such as tensile strength, elongation, drapeability, thermal resistance, and stiffness of the polyester fabric were measured by the standard established methods such as grab tensile test method, Elmendorf tear tester as per ASTM D1424 – 2009, Cusik Drapemeter, $R_{th} = L/k, ((m^2 \text{ } ^\circ\text{C})/W)$, and Shirley stiffness tester respectively [Pajgrt, O, & Reichstadter, B 1979](#), [Pellew, C 1998](#), [Peters, RH](#).

2.2.6. ABSORPTION OF THE POLYESTER FABRIC

The absorption characteristics of the polyester fabric (desized, sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) such as, drop absorbency, water retention and wicking were determined as per the AATCC test methods [Petukov, BV 1963](#), [Prorokova, NP, Vavilova, SY, & Prorokov, VN 2007](#), [Prorokova, NP, Vavilova, SY, & Prorokov, VN 2007](#), [Rajendran, S, & Mishra, SP 2007](#).

2.2.7. SEM STUDY OF THE POLYESTER FABRIC

The polyester fabric (desized, sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) was subjected for scanning electron microscope study using 30kV scanning electron microscope, JEOL (Japan) Model JSM-6360 [Ramachandran, T, & Kesavaraja, N 2004](#), [Roberts, RC 1969](#).

2.2.8. FTIR ANALYSIS OF THE POLYESTER FABRIC

FTIR analysis was performed on the polyester fabric (sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) for studying the different functional groups, by the Fourier Transform Infra Red (FTIR) spectrophotometer (Shimadzu, Japan) [S.Y. Oh, D.L.Yoo, Y. Shin, H.C. Kim, H.Y. Kim, Y.S. Chung, W.H. Park, J.H. Youk 2005](#), [Sanders, EM, & Zeronian, SH 1982](#).

2.2.9. XRD ANALYSIS OF THE POLYESTER FABRIC

XRD analysis was performed on the polyester fabric (sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) to understand the unknown crystalline materials using Shimadzu XRD6000 technique [Sanders, EM, & Zeronian, SH 1982](#), [Saville, B.P, 2004](#), [Uchida, E, Uyama, Y, & Ikada, Y 1989](#).

3. RESULTS AND DISCUSSION

3.1. PHYSICAL PROPERTIES OF THE POLYESTER FABRIC

The physical properties, such as tensile strength, elongation, stiffness, drape coefficient and thermal resistance of the polyester fabric (desized, sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) are given in the [Table 1](#). From the table it is visible that as the polyester fabric is undergone subsequent treatments, the tensile strength decreases both in the warp and weft way respectively in a considerable manner. However, the elongation is increased subsequently. In the same way, stiffness and thermal resistances are reduced; and drape coefficient is increased in a marginal manner. All these changes are due to the effect of the sodium hydroxide and the polyvinyl alcohol treatments. Even though the polyester fabric was treated with sodium hydroxide (5%, 10% and 15% (w/v)) and polyvinyl alcohol (3%, 5% and 10% (w/v)) in different concentrations; only the optimum value is fixed for the different studies. Accordingly, the sodium hydroxide concentration is fixed as 10% (w/v) and polyvinyl alcohol concentration is fixed as 5% (w/v) respectively. Below and above these optimum values the effect was noticed to be very less, and hence it is continued further with the above noted optimum values. Also for the confirmation of the effect of these applications, finally the polyester fabric was dyed with disperse dye.

| Table 1 Physical properties of the polyester fabric | | | | | | | | | |
|---|--------------------------------|----------------------|-------|----------------|------|-------------------------------|------|-----------------------|---|
| S. No. | Treatments on polyester fabric | Tensile Strength (N) | | Elongation (%) | | Stiffness [Bending length cm] | | Drape coefficient (%) | Thermal resistance (m ² .mk/w) |
| | | Warp | Weft | Warp | Weft | Warp | Weft | | |
| 1 | Desized | 385.6 | 364.2 | 8.8 | 8.3 | 0.81 | 0.78 | 93.65 | 94.25 |
| 2 | Sodium hydroxide treated | 379.3 | 358.7 | 9.2 | 8.7 | 0.8 | 0.77 | 94.26 | 93.82 |
| 3 | Polyvinyl alcohol treated | 381.5 | 360.6 | 9.3 | 8.8 | 0.8 | 0.77 | 94.24 | 93.65 |
| 4 | Dyed | 381.8 | 361.2 | 9.3 | 8.8 | 0.8 | 0.77 | 94.25 | 93.67 |

3.2. ABSORPTION CHARACTERISTICS OF THE POLYESTER FABRIC

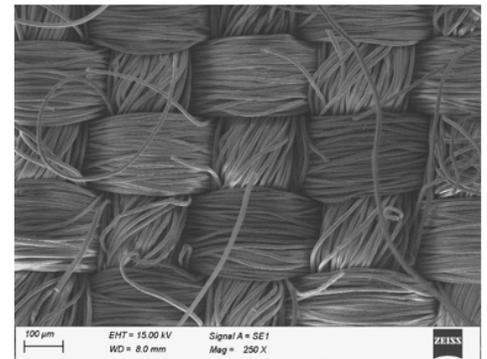
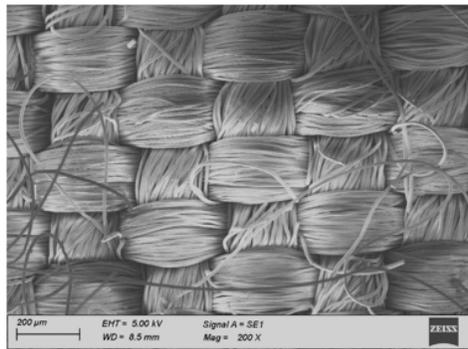
The absorption characteristics like drop absorbency, water retention and wicking of the polyester fabric (desized, sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) are given in the Table 2. It is observed from the Table 2 that as the polyester fabric is undergone subsequent treatments (desizing, sodium hydroxide treatment, polyvinyl alcohol treatment), the absorption characteristics (drop absorbency, water retention and wicking) are increased in overall manner. In drop absorbency, the desized polyester fabric after treatment with sodium hydroxide (10% w/v) and subsequently with polyvinyl alcohol (5% w/v) the water drops are absorbed in less time. Correspondingly, the water retention on these polyester fabrics is considerably more in a respective manner. In the similar way, the wicking tendency is also increased with respect to this trend. All these increased effects are due to the influences of sodium hydroxide and polyvinyl alcohol in the polyester fabric. The sodium hydroxide at this specific concentration (10% w/v) induces the swelling aspects in the polymer chain and subsequently the application of polyvinyl alcohol (5% w/v) gives the reaction over the partially hydrolyzed polyester polymer and increased the reactivity and hence the hydrophilicity.

| Table 2 Absorption characteristics of the polyester fabric | | | | |
|--|--------------------------------|----------------------------|---------------------|-------------------------------|
| S. No. | Treatments on polyester fabric | Absorption characteristics | | |
| | | Drop absorbency (sec) | Water retention (%) | Wicking (cm) [for 45 minutes] |
| 1 | Desized | 320 | 120 | 3.2 |

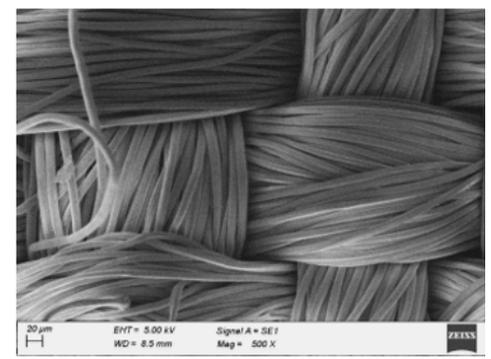
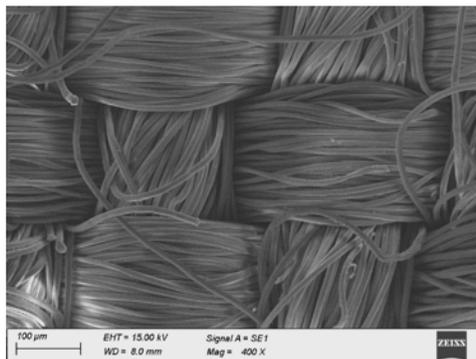
| | | | | |
|---|---------------------------|-----|-----|------|
| 2 | Sodium hydroxide treated | 190 | 180 | 8.6 |
| 3 | Polyvinyl alcohol treated | 165 | 190 | 10.7 |
| 4 | Dyed | 167 | 189 | 10.7 |

3.3. SEM STUDY OF THE POLYESTER FABRIC

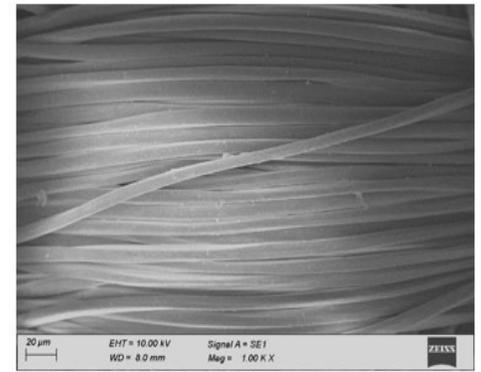
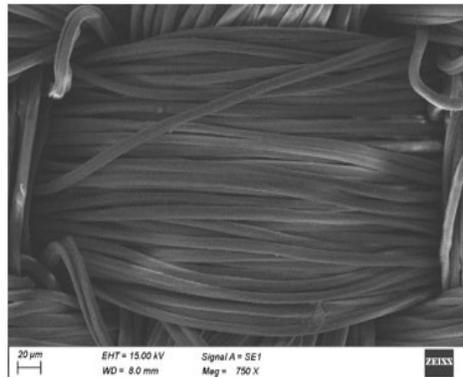
The polyester fabrics subjected with different treatments (desized, sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) were undergone for SEM studies and the images of the them are shown in [Figure 1](#). It is seen from these figure that there is a subsequent differences in the images of the SEM micrographs of the polyester fabrics (desized, sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed). The improved effect subsequently is due to the effect of sodium hydroxide treatment and the periodical polyvinyl alcohol treatment and dyeing. A focused beam of high-energy electrons is used in scanning electron microscope to generate the variety of signals at the surface of solid textile samples. The electron-sample interactions provide signals that reveal the information about the samples including the texture (external morphology), crystalline structure and orientation of materials of the sample. The scanning electron microscope also provides the capability of performing analyses of selected point locations on the sample [Roberts, RC 1969](#), [Usenko, V 1979](#).



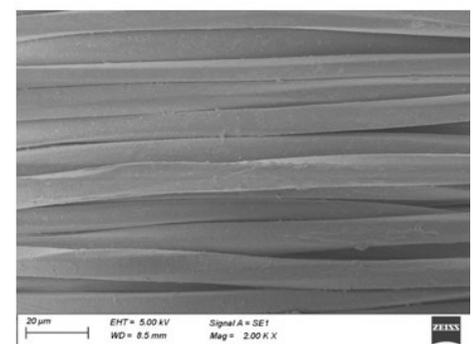
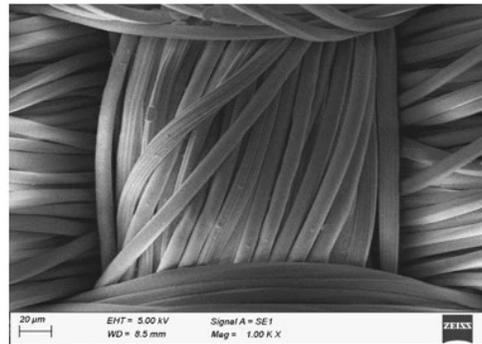
a) Desized polyester fabric



b) Sodium hydroxide treated polyester fabric



c) Sodium hydroxide and polyvinyl alcohol treated polyester fabric



d) Sodium hydroxide, polyvinyl alcohol treated and dyed polyester fabric

Figure 1 SEM Micrographs of the Polyester Fabrics (a-desized, b-sodium hydroxide treated, c-polyvinyl alcohol treated and d-the subsequent dispersed dyed)

3.4. FTIR ANALYSIS OF THE POLYESTER FABRIC

The polyester fabrics treated with different treatments (desized, sodium hydroxide treated, polyvinyl alcohol treated and the subsequent dispersed dyed) were undergone for FTIR study and the graphs are shown in the [Figure 2 FTIR graphs of the Polyester Fabrics \(a-sodium hydroxide treated, b-polyvinyl alcohol treated and c-the subsequent dispersed dyed\)](#) and [Figure 2a](#) respectively. These graphs give the indication about the effect of sodium hydroxide and the subsequent polyvinyl alcohol on the polyester fabrics. From the Figures 2 and 2a it is revealed that as the polyester fabrics are treated with sodium hydroxide and the polyvinyl alcohol, the peak area of FTIR graph is differed which gives the indication for the effect of application on the polyester fabric. It can be observed that the broad peak in the spectra of polyvinyl alcohol treated polyester fabrics has influenced in peak intensity which indicates that the surface hydroxyl (OH) groups in the polyester fabric and indicates the presence of polyvinyl alcohol over the polyester fabric surface. The IR bands shown are in the region of 1700–600 cm and correspond to C=O, C–O and C–H vibrations respectively 37, 41, 42. The important other peaks are due to the O–H stretching which is around 3600 to 3700 with reference to the standard data shown in the [Table 3](#).

Table 3 Details of the standard data for the FTIR spectra

| S. No. | Peak Range(cm ⁻¹) | Functional Groups |
|--------|-------------------------------|--|
| 1 | 3600-3700 | Non bonded hydroxyl group-OH- |
| 2 | 3300-3400 | Alkyne -C-H- stretch |
| 3 | 3200-3300 | Hydroxyl group (H-bonded -OH- stretch) |
| 4 | 3000-3200 | Aromatic ring (-C-H- stretch) |
| 5 | 2900-3000 | Methylene -CH- stretch |
| 6 | 2700-2800 | Terminal aldehyde -CH- stretch |
| 7 | 2600-2700 | Hydrogen bonded -OH- group |
| 8 | 2500-2600 | Thiols (-S-H- stretch) |
| 9 | 2400-2500 | -CH- stretch of aromatic compounds |
| 10 | 2300-2400 | -OH-stretching of Carboxylic acid |
| 11 | 2200-2300 | Cyano compounds, disubstituted alkynes |
| 12 | 2100-2200 | C-triple bond-C- stretch |
| 13 | 2000-2100 | Cyanide ion and related ion |
| 14 | 1800-2000 | Transition metal carbonyl group |
| 15 | 1700-1800 | Carbonyl group |
| 16 | 1600-1700 | -C-double bond-C stretch |
| 17 | 1500-1600 | Aromatic ring stretch-NH-bend |
| 18 | 1400-1500 | Organic Sulphates |
| 19 | 1300-1400 | -OH- bend |
| 20 | 1200-1300 | Aromatic primary amine -CN- stretch |
| 21 | 1100-1200 | Secondary amine -CN- stretch |
| 22 | 1000-1100 | -C-C- stretch |
| 23 | 900-1000 | Cyclo hexane ring vibrations |
| 24 | 800-900 | Peroxides -C-O-O-stretch |
| 25 | 700-800 | Skeletal -C-C- vibrations |
| 26 | 600-700 | Aliphatic Bromo compounds |
| 27 | 500-600 | -C-I- stretch |

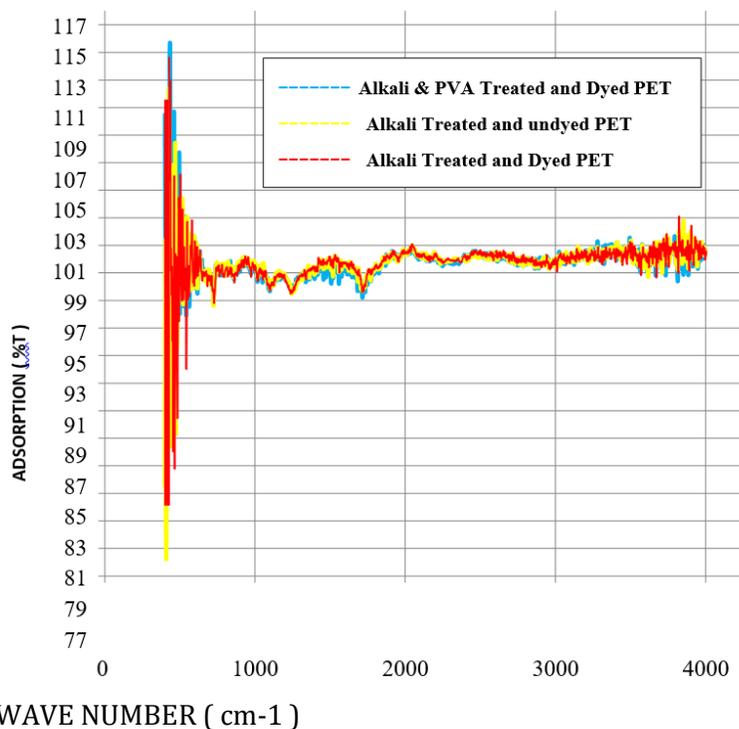
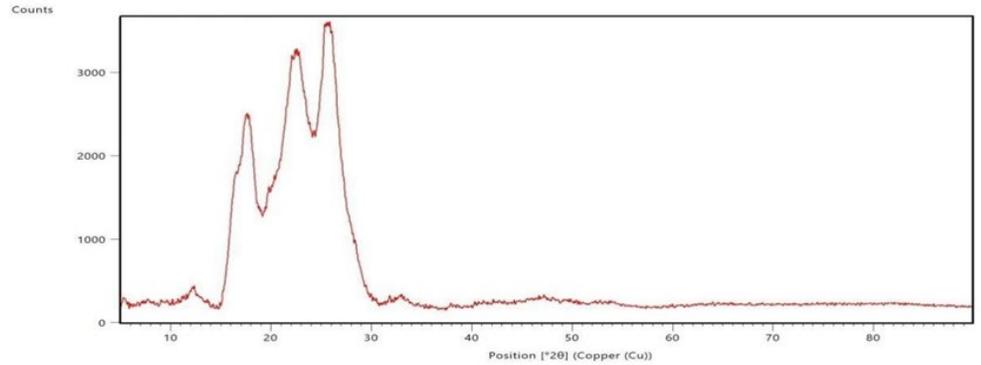


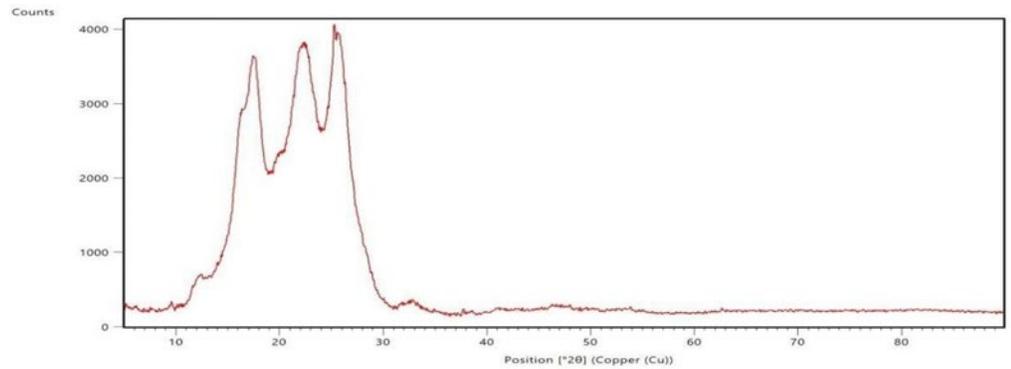
Figure 2a Combined FTIR graphs of the polyester fabric (a - sodium hydroxide treated, b - polyvinyl alcohol treated and c - the subsequent dispersed dyed)

4. XRD ANALYSIS OF THE POLYESTER FABRIC

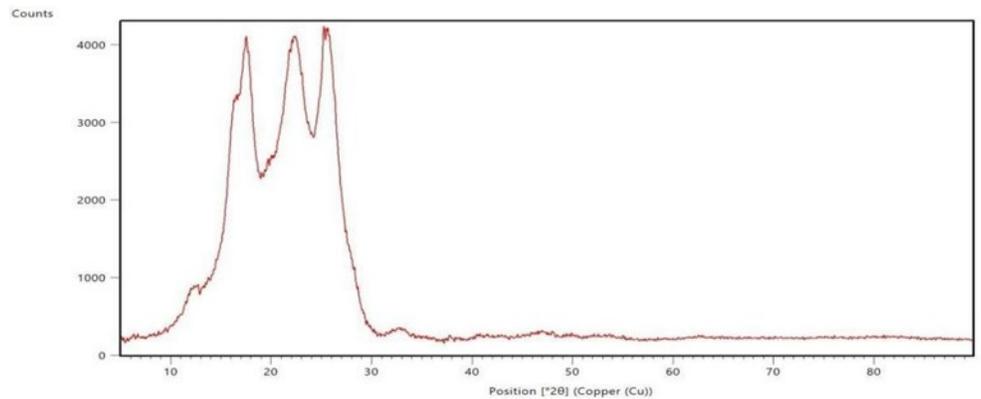
The polyester fabrics treated with sodium hydroxide, sodium hydroxide followed by polyvinyl alcohol, and their subsequent disperse dyeing respectively are subjected for XRD study and the graphs are shown in the [Figure 3 XRD spectrograms of the Polyester Fabrics \(a-sodium hydroxide treated, b-polyvinyl alcohol treated and c-the subsequent dispersed dyed\)](#). These spectrograms give the indication about the effect of sodium hydroxide treatment and the polyvinyl alcohol treatment on the polyester fabrics. From the [Figure 3 \(a, b & c\)](#) it is revealed that as the polyester fabrics are treated with sodium hydroxide, polyvinyl alcohol and their subsequent disperse dyeing, the bandwidth of the XRD graph is differed which gives the indication for the effect of application in these conditions on the polyester fabric. X-ray diffraction is a common materials characterization technique that allows for identification of crystal orientations and inter-atomic spacing. X-rays are used for this because the wavelength is on the same length scale as inter-atomic spacing and lattice parameter values. The presence of characteristic peaks corresponding to the polyester crystalline in the XRD pattern of the respective treated fabrics indicates that the treatment of sodium hydroxide and polyvinyl alcohol on the polyester fabric surface does not affect the inherent crystalline structure of the polymer; rather it enhances the increase of the hydrophilic functional groups [Uchida, E, Uyama, Y, & Ikada, Y 1989, Zhang, C, Yang, F, Wang, W, & Chen, B 2008, Zhifeng, Z, & Kun, Q 2007.](#)



a) Sodium hydroxide treated polyester fabric



b) Sodium hydroxide and polyvinyl alcohol treated polyester fabric



c) Sodium hydroxide, polyvinyl alcohol treated and dyed polyester fabric

Figure 3 XRD spectrograms of the Polyester Fabrics (a-sodium hydroxide treated, b-polyvinyl alcohol treated and c-the subsequent dispersed dyed)

5. CONCLUSION

From this research work, it is observed that the physical properties of the sodium hydroxide treated and polyvinyl alcohol treated polyester fabric are not affected considerably, rather maintained in the expected limit. The absorption characteristics of the sodium hydroxide and polyvinyl alcohol treated polyester fabric are improved considerably. The SEM micrographs reveal the presence of the impact of the polyvinyl alcohol in the polyester fabric. The FTIR graphs indicate the influence of the application of sodium hydroxide and the subsequent polyvinyl alcohol treatment as well as disperse dyeing in the polyester fabric to secure the value of hydrophilic characters. The XRD spectrogram pronounce the good effect of treatments of sodium hydroxide, polyvinyl alcohol and the subsequent disperse dyeing in the polyester fabric

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