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# EXAMINATION OF SOME COMFORT RELEATED PROPERTIES OF SPORTSWEAR FABRIC COATED WITH POLYURETHANE FOAM

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**Abstract-Waterproof, breathable fabrics provide protection against rain and wind, besides delivering super moisture in the form of vapor. This helps to keep the person dry, cool and comfortable. Special films are used in such products to provide both permeability and resistance. In this study, some comfort related properties of polyurethane foam coated fabrics which can be used in sportswear garments clothes have been investigated.**

**Woven fabrics produced from cotton / polyester blend yarns were coated with waterproof and breathable polyurethane foam film with different thickness and different density. Reactive polyurethane polymer with solubilized solid and heat effect was used as binder.**

**The coated fabrics were tested for some comfort related properties such as water vapor permeability, air permeability and water resistance. SEM images were taken to investigate morphological properties. The results showed that the water vapor permeability of coated fabrics decreased due to the increased interaction between the polymer chains due to presence of ester groups. Coated cotton/polyester blend gave good abrasion resistance compared to uncoated fabric.**

**Keywords: Polyurethane foam, coating, waterproof, breathable fabric.**

## 1. INTRODUCTION

Textile surface materials coated with chemical structures have been developed continuously for several decades. The basic substrate of the surface material is mostly textile fabric coated on one or both sides with one or more polymer layers. This kind of product with basic textile material has many improved properties and multiple advantages over the textile material [1].

The polymer coating must be adhered to the textile material and a blade or a similar interval controls the thickness of the viscous polymer. The coated fabric is heated for polymerization and the polymer is cured [2]. Waterproof breathable fabrics are designed for use in garments that protect the users from wind, rain or even loss of body heat [3]. Waterproof fabric completely prevents the penetration and absorption of water, in contrast to water repellent fabric, which only delays the penetration of water [4].

It is important to realize that coating formulations consist of several additives depending upon the nature of the polymer and the necessary additives for the specific end use [5]. Polyurethanes(PU) are formed from diisocyanates, polyols, amines, catalysts and additives [6]. The application of PU on breathable waterproof fabric coatings requires a balance of water vapor permeability (WVP) and water resistance, which can be achieved by tailoring hydrophilic and hydrophobic segments [7]. Thickeners used in textile coating are high molecular weight compounds giving viscous pastes in water. Synthetic thickeners are mostly preferred when compared to emulsions and natural thickeners [8].Synthetic acrylic based thickeners used in coating paste are anionic cross linked acrylic copolymer emulsions which on addition of an alkali. They become highly viscous. Its high thickening power with a distinctly pseudo plastic flow enables it to penetrate textile material evenly. Cross linking agents improve the bond between the textile material and the coated polymer [9]. Polyurethane coatings show outstanding resistance to abrasion combined with good resistance to water and solvents, in addition they offer good flexibility. The chemistry of the diol can be varied considerably so as to convey water vapour to the coating. It is important that the foam has pores to allow penetration of water vapour but they should be small enough to prevent liquid water penetration.

Waterproofness and breathability can be achieved with coated fabrics. Waterproof and breathable fabrics provide protection against rain and wind. In addition, they provide the transmission of super moisture in the form of vapor. This helps to keep the person dry, cool and comfortable Special films are used in such products. The aim of this study is to examine some comfort related properties of coated fabrics designed for sports. For this purpose, the surfaces of the cotton / polyester blend woven fabrics were coated with waterproof and breathable polyurethane foam films of different thickness and different

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density. The fabrics obtained after foaming were tested for some physical and comfort properties. The effects of different coating thicknesses and the usage of different binders on the coating fabric performance were investigated.

## 2. MATERIALS AND METHOD

Pre-treated cotton / polyester woven fabrics were used in the experimental part. Three different types of polymers i.e, polyurethane, acrylic and fluorocarbon polymer combination, were used as coating materials. Polyurethane and acrylic are commonly used in coating while fluorocarbon polymer is a product used which is for special purposes.

### *2.1.Materials*

The properties of the fabric which was used in the experiments were given in Table 1.

Table 1. Technical Properties of Fabric

| Fabric | Warp Density(yarn/cm) | Weft Density(yarn/cm) | Fiber Blend | Weight (g/$m^2$ ) |
|---|---|---|---|---|
| 2/2 Rib Weave | 40 | 20 | 50% cotton, 50% polyester | 304 |

Polyester/cotton woven fabric was purchased from OZTEK STAMPA and used as base fabric for coating.

Polyurethane coating baths were prepared by mixing different ratios of binder, foam agent and crosslinker to form the cured film. In the study, five woven fabric specimens were first impregnated with a pick-up of 100% by using a bath containing 40 g / L of fluorocarbon and 60% acetic acid and then dried at 100 $^0$C for 2 minutes. The first three fabric samples were coated in three different thicknesses with 80% polyurethane binder, 5% foam agent, and 15% cross-linker-coated coating bath. Coating thicknesses were 0,05mm, 0,2 mm and 0,5 mm. In the process; fluorocarbon is applied, then fluorocarbons combine to form film during fixation. In this film, the perfluorinated parts of the polyacrylates are oriented towards the upper surface, leading to water repellency. After fluorocarbon pretreatment, the remaining two samples were coated with 0,2mm coating thickness bath containing 80% acrylic binder, foam agent and crosslinker at the same ratios. Extra fluorocarbon treatment and drying process was applied to the last coated fabric sample with the same coating ratios.

### *2.2. Coating of Fabrics*

Polyester/cotton woven fabrics were coated by a knife over roller machine. The coated fabrics were dried at 100 ° C for 2 min and then cured at 160 ° C for 2 min.

### *2.3 Physical Properties of Coated Samples*

The water resistance(hydrostatic pressure) test was carried out according to AATCC 127 using SASMIRA developed hydrostatic Head & Domb tester. Distilled water at a temperature of 20±2 $^0$C was used in the experiment. The rate of increase in water pressure was maintained at 30±3 cm $H_2O$/min. The pressure was recorded at a point when water penetrated the fabric at the third place. The unit was expressed as cm $H_2O$ [10].

The water vapour permeability of the coated samples was measured by using the Permetest instrument according to ISO 9920 standard.

The air permeability of coated samples were carried out according to ISO 9237 standard. In the test samples were subjected to an air flow at 100 Pa.

The abrasion resistance of coated substrates were measured according to ASTM D4966 using Martindale abrasion tester.

## 3.RESULTS AND DISCUSSION

### *3.1. Water Vapour Permeability*

The water vapor permeability values obtained after fluorocarbon pretreatment and polyurethane coating with different thicknesses were given in the Figure 1.

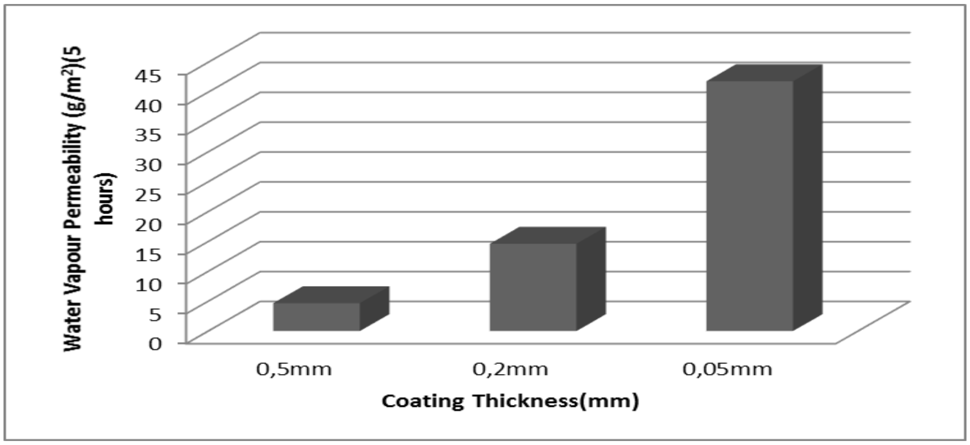


Figure 1. Water vapor permeability values according to coating thickness

In Figure 1, the water vapor permeability of the fabrics decreased as the coating thickness increased. Therefore, the thinnest fabrics had the best water vapor permeability. However, a fundamental problem arises regarding this finding. When the fabric is thin; the high water vapor permeability causes the thermal resistance to drop and consequently this causes a sudden drop in body temperature due to rapid heat transfer.

The coating bath I contains fluorocarbon(400g/l), acrylic binder(400g/l),crosslinking agent(150g/l),foam agent(150g/l).

The coating bath II contains polyurethane (900g/l), crosslinking(100g/l).

The water vapor permeability values obtained from coating bath II with different coating process were given in the Figure 2.

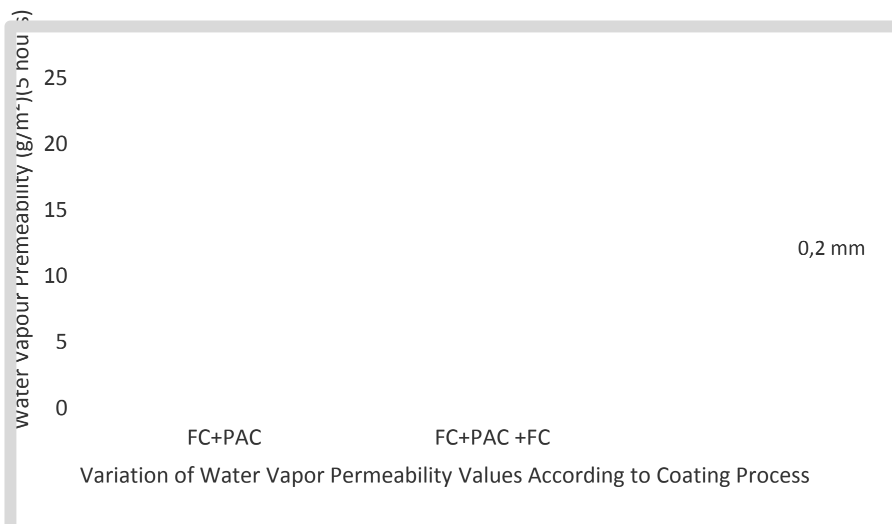


Figure 2. Water vapor permeability values according to coating bath I process.

The fabric samples presented in Figure 2 were coated with a coating comprising of fluorocarbon, acrylic, cross-linker and foam forming. The chemical functional groups are represented as linear $CF_2$ , $-CH_2=CH$, -COOH ,PU-foam chemical substances, respectively. The water vapor permeability value was measured 23,103% after drying and fixing the coated fabric sample. After fluorocarbon drying was applied to the fabric samples which were coated with the same binders, water vapour permeability decreased to 12,39%.The water vapor permeability value is decreased due to the oleophobicity and the water pores will be blocked.

*3.2. Air Permeability*

The air permeability values obtained with different coating thicknesses were given in Figure 3.

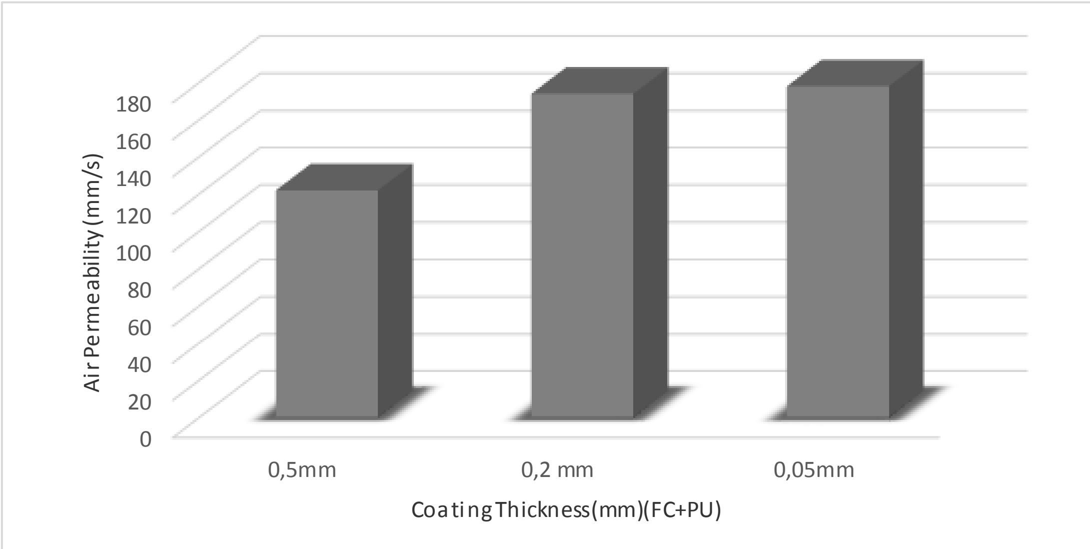


Figure 3. Variation of air permeability values according to coating thickness

FC+PU: Flurocarbon+Polyurethane coating process
In figure 3, the air permeability of the fabrics increased as the coating thickness increased.

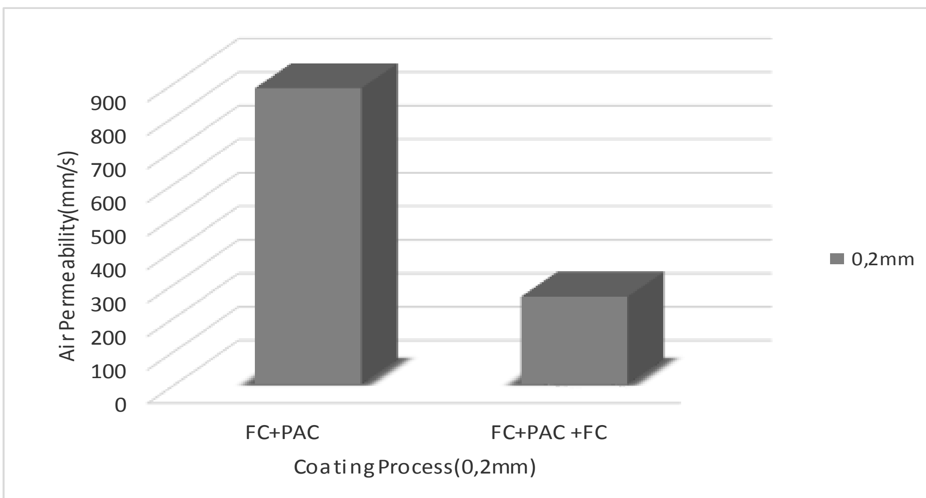


Figure 4. Variation of air permeability values according to coating process

FC+PAC: fluorocarbon+polyarcylate coating
FC+PAC+FC: fluorocarbon process after fluorocarbon+polyacrylate coating
In Figure 4, air permeability value was obtained 883 mm/s after coating, drying and fixing fabric samples with baths containing fluorocarbon, acrylic, crosslinker and foam forming chemical substances. Air permeability decreased to 261 mm/s after the post-coating fluorocarbon process.

*3.3. Water Resistance*

The water resistance performance, also known as the ability to provide protection against water spillage, was tested both in laboratory tests and in clothing tests. Water resistance measurement is based on the resistance against water pressure increasing from the bottom of the fabric sample. For this purpose, hydrostatic pressure test is widely applied. The results for the hydrostatic water pressure test are measured at the point where the first drops appear in three separate areas on the specimen. The water resistance values obtained by coating the fabric samples in different thicknesses with the coating bath I were given in Figure 5.

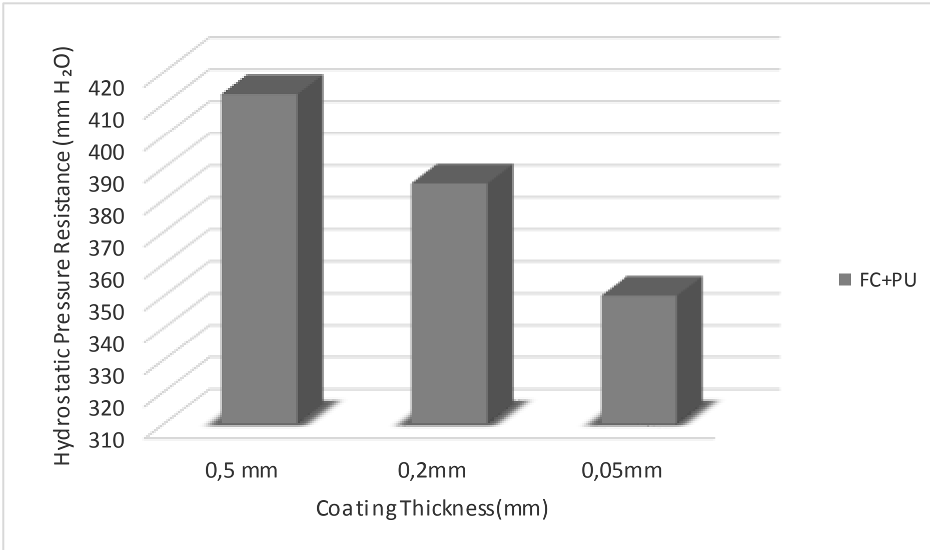


Figure 5. Hydrostatic pressure resistance values according to coating thickness

FC+PU: fluorocarbon+ polyurethane coating
The water resistance values obtained as a result of coating the cotton/polyester blend fabrics with acrylic, fluorocarbon, foam agent and crosslinker in different processes with coating bath were given in Figure 6.

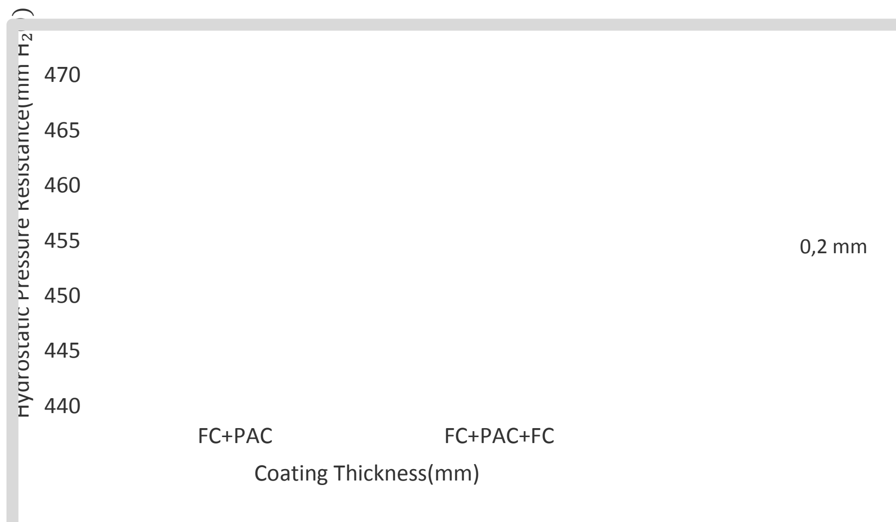


Figure 6. Variation of hydrostatic pressure resistance values according to coating process

FC+PAC: fluorocarbon+polyarcylate coating
FC+PAC+FC: fluorocarbon process after fluorocarbon+polyacrylate coating
In Figure 6, the water repellency values were measured on the fabric samples which were coated with acrylic, fluorocarbon, crosslinker and foam-forming bath, dried and fixed. Water resistance values decreased significantly. The reason could be explained by the penetration of the arcylic coating between the yarns and closing the pores in the surface to some extent.

*3.4. Abrasion Resistance*
In abrasion resistance; the fibers on fabric surface must be resistant to abrasion force applied on the fabric sample. The coated and uncoated samples were subjected to the abrasion test under the same testing conditions. The results given in Table 2 showed no changes in sample thickness or weight loss 5000 abrasion cycles. However, after 5000 cycles, fabric thickness and fabric weight decreased. Also, coated fabric samples had better good abrasion resistance when compared to uncoated fabric samples. The abrasion mechanism of foam coating is a complex phenomenon and associated with the properties of fibers, yarns, fabrics structure and the applied coating treatments.

Table 2. Effect of coating thickness on abrasion resistance
Abrasion Resistance-Weight Loss(%)

| | 0,05 mm coating thickness | 0,2 mm coating thickness | 0,5 mm coating thickness |
|---|---|---|---|
| Uncoated fabric | 1,14 | 0,9 | 0,56 |
| Coated fabric | 0,3 | 0,22 | 0,15 |

*3.4. Surface Image analysis*
Figure 7 shows the microscopic images of polyurethane foam coated and uncoated fabric samples. The surface of the uncoated fabric appeared smooth whereas coated one showed deposition of coating on the yarn surface.

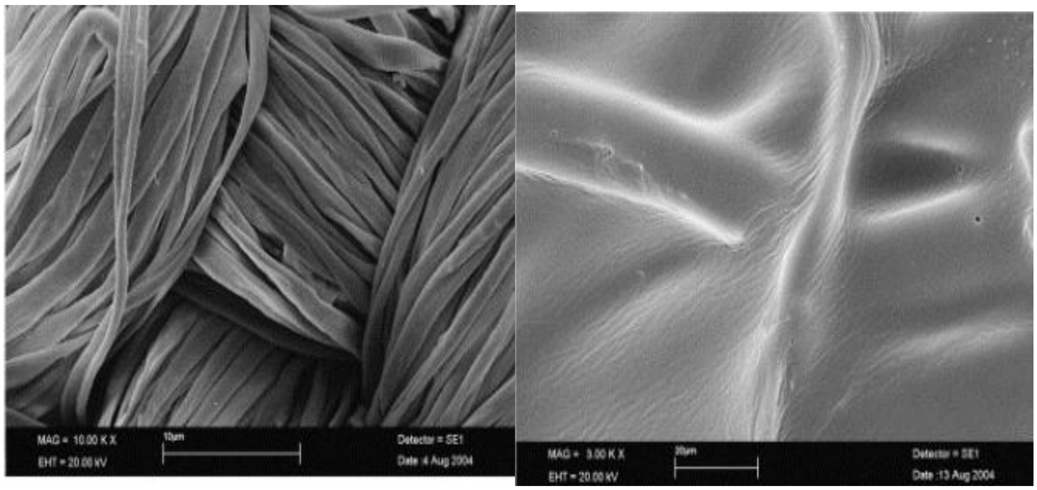


Figure 7.Microscopic images of uncoated and coated cotton/polyester fabrics.

*3.5. FTIR Analysis*
The structural changes in coating polymers were characterized by Fourier Transform Infrared Spectra(FT-IR). FT-IR was recorded by using an İnfrared Shimadzu FT-IR Spectrometer with 1cm$^{-1}$ resolution and in range from 2000-750cm$^{-1}$.
The Fourier transform infrared spectrum of uncoated fabric besides PU and PAC were shown in Figure 8. The most important characteristic features of the PU are the presence of bands at a small peak in the region between 800 and 850 cm$^{-1}$ can be accounted for out-of-plane bending of aromatic ring system. The peak at 1250 cm$^{-1}$ may be due to C-O stretching of the polymer back bone. The peak at 1040 cm$^{-1}$ was attributed to the O-C=O stretching of urethane/ester group.
The peak at 1557-1580 cm$^{-1}$(C-N stretching and N-H bending), at 1600 cm$^{-1}$(C-C stretching vibration), at 1635 cm$^{-1}$(C=C stretching vibration in aromatic ring). A broad peak at 1730 cm$^{-1}$ is characteristic of carbonyl stretching of unsaturated ester.

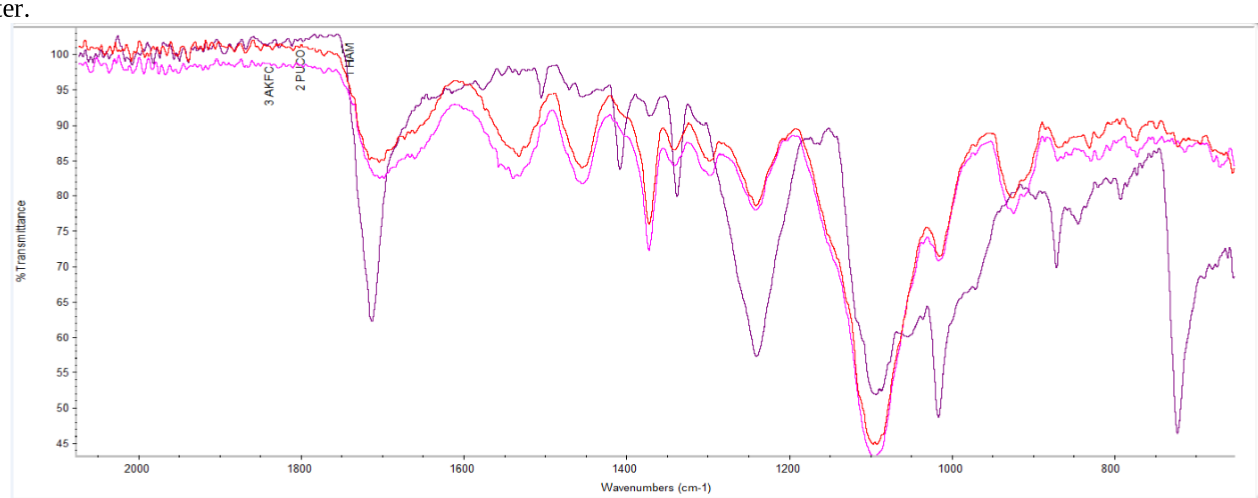


Figure 8. FTIR Spectra of uncoated cotton/polyester fabric, PU and PAC Coating

In the case of polyurethane treated fiber, the width of the peak had reduced and the peak value has been shifted to higher wave number, that is, 1750 cm$^{-1}$. Due to ester linkage of acrylic monomer band at 1602 cm$^{-1}$ and 1536 cm$^{-1}$ confirmed the formation of urethane linkages. They were attributed to tertiary-amide carbonyl and N-H bending. Further the absence of any band at 2270 $cm^{-1}$ in the spectrum indicated that no unreacted isocyanate was present. This trend was been supported by the results of SEM studies.

## 4. CONCLUSIONS

The below conclusions could be drawn:

1.As the coating thickness increased; the water vapor permeability of the fabric decreased. Therefore, the thinnest fabrics have the best water vapor permeability. However thermal resistance may be low in thin fabrics and rapid way heat transfer causes the body temperature to drop suddenly. Multilayer fabrics solve this problem. Thus, in order to improve the vapor permeability of multi-ply textile fabrics which are worn in cold climates, at least one of these layers should be produced as a very thin and highly permeable film layer or coating. This prevents the loss of high heat, sweating through the body heat to prevent the rise to the upper levels.

2.After coating with polyurethane and foam agent; air permeability values increased on the coating thickness. The air permeability values after coating, drying and fixing the fabric samples with bath containing fluorocarbon, acrylic, crosslinking and foam forming chemical substances have increased even more than coating with polyurethane. The amount of acrylic used in the coating baths ensured the pores to be more rigid and brittle in the post-coating of fabrics. This caused an increase in air permeability values in fabric samples after coating.

3.Application of the thicker coating on woven fabrics increased its rigidity. In other words, coatings increases the of the woven fabrics.

4.After coating with the same materials and drying with fluorocarbon process, the water resistance values decreased. This could be explained by the fact that acrylic coating material penetrates between the yarns and closes the pores in the surface to some extent.

5.Coating treatment and penetrated types and concentrations of the chemicals used in the treatment processes also the parameters affected the abrasion characteristics of the fabrics. The thickness and weight of samples reduced after 5000 cycles and coated fabrics gave good abrasion resistance when compared to fabrics. Therefore, it could be concluded that using coating bath I as coating material is a better application when compared to coating bath II.

## 5. ACKNOWLEDGMENTS

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