(REFEREED RESEARCH)

INVESTIGATION OF SOME COMFORT PROPERTIES OF FABRICS LAMINATED WITH DIFFERENT TYPES OF MEMBRANES

FARKLI MEMBRANLARLA LAMİNE EDİLMİŞ KUMAŞLARIN BAZI KONFOR ÖZELLİKLERİNİN İNCELENMESİ

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ABSTRACT

The aim of this study is to determine and evaluate some comfort properties of laminated fabrics obtained with different membranes. In the study, 100% PES woven fabric was laminated using membrane materials as PU (polyurethane), PES (poliester) and PTFE (polytetrafluoroethylene). Water repellent finishing process was applied to these fabrics and some comfort tests of the fabric were carried out in two groups. These groups are; Group 1, subjected to lamination after the application of water repellent finishing process; group 2, subjected to water repellent finishing process after lamination process. The comfort tests included water repellent, air permeability, water impermeability, and water vapor transmission tests. The obtained results from experimental studies were compared with graphics and thus interpreted. In conclusion, it could be recommended to apply water repellent processes after lamination, in contrast to traditional method using water repellent process prior to lamination.

Key Words: Lamination, Membrane, Water repellent finishing process, Water vapor transmission, Water impermeability.

ÖZET

Bu çalışmanın amacı, farklı membranlarla lamine edilmiş kumaşların bazı konfor özelliklerini belirlemek ve değerlendirmektir. Çalışmada %100 PES dokuma kumaş, PU, PES ve PTFE membranlarla lamine edilmiştir. Bu kumaşlara su iticilik apresi uygulanmış ve konfor testleri laminasyon öncesi ve laminasyon sonrası su iticilik apre prosesli olmak üzere iki grupta yürütülmüştür. Hava geçirgenliği, su iticilik, su geçirmezlik ve su buharı geçirgenliği, kumaşlara uygulanan konfor testleridir. Elde edilen sonuçlar grafiklerle karşılaştırılmış ve yorumlanmıştır. Neticede, geleneksel yöntemin yerine, laminasyon sonrası su iticilik prosesinin uygulaması tavsiye edilmektir.

Anahtar Kelimeler: Laminasyon, Membran, Su iticilik apresi, Su buharı geçirgenliği, Su geçirmezlik.

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1. INTRODUCTION

Coating and lamination technologies are used in textile production processes for promoting functional and performance properties of textile products in order to meet consumer demands and to develop new fields of use. In the past, one or both sides of textile surface were covered with a polymer substance using coating and lamination method to decrease permeability properties and thus to protect from unfavorable wind and other weather conditions. On the other hand, modern coating and lamination technologies are used in protective sport textiles produced for increasing esthetic, decorative as well as technical and functional properties of textile products, especially if certain parameters like high performance, durability, and comfort are important (1). Properties expected from clothes have been changed with the increasing living standards at present, which has extended the usage area of laminated fabrics and improved the comfort properties (water vapor transmission, air permeability etc.) to some degree in these products. The review of the previous studies and applications made in this field revealed the following evaluations. Samms (2) compared monolithic film and micro porous film technologies in his study on thermoplastic polyurethane chemistry and the effects of chemistry on breathing capability. He experimentally investigated the properties of two kinds of thermoplastic PU produced by a firm, and concluded that both had good WVTR (water vapor transmission rate) which was close to micro porous PTFE. Jeong and An (3) compared the properties of fabrics subjected to air permeable and water repellent PU coating produced for out wear and PTFE lamination. Water vapor transmission, water resistance, water repellent, air permeability and other characteristics were experimentally determined for wet and dry conditions of fabrics made by two different coating methods. Consequently, they determined that water vapor transmission of fabric subjected to wet coating increased, while water resistance decreased. On the other hand, the exact opposite results were obtained in fabrics subjected to dry coating. Water vapor transmission and air permeability were determined to decrease with higher coating density, while water resistance increased. Schmidt et al. (4) investigated water vapor transmission through porous membranes by gravimetric method using hydrophobic polyurethane membrane and PES filter (for impermeability). Changes in volume were constantly observed under isothermal conditions, and thus water vapor transmission rate, permeability and diffusion coefficients were determined. Certain factors including porous structure and width were effective on water vapor transmission rate, and it was suggested that this method could be used to measure transmission rates of other volatile fluids in different membrane structures. Şahin (5) used polyurethane coating on different fabrics (micro PES, PA, PES, PES/PA) at different proportions by using knife coating method among fabric coating methods, and measured the water proof and resistance performance properties of these fabrics. According to the results of water proof test, 70-fold increase was observed between unprocessed and 70 g PU coated micro PES fabrics. In a study on laminated fabrics made of different fiber types, each side of supreme knitted fabrics made of viscose, polyester, cotton and bamboo fibers was laminated with water proof and air permeable polyurethane films with identical slimness but different density. Solid reactive polyurethane adhesive melting with heat was used as fastener. Samples were tested for physical and comport performance properties. The effects of fibers with different membrane structures on knitted fabrics were comparatively investigated in the experiments (6). In a study investigating the comfort properties of air permeable and membrane laminated fabrics, following the selection and procurement, fabrics were subjected to water vapor transmission, air permeability and water proof tests. As a result of the study, it was determined that water vapor transmission rate decreased as the thickness of membrane used in lamination increased, and membrane characteristics (micro porous or non-porous) had different effects on water vapor transmission rate in different environments. In addition, air gap between body and cloth was reported to considerably diminish water vapor transmission (7). Frydrych et al. (8) analyzed the chosen physical properties of membranes providing high comfort in clothes. Primarily, clothes with good thermal properties were produced by designing heat-insulated clothes and combining them with fabrics, and thermal insulation parameters of membrane clothes were tested. Measurements were made on 12 different clothes using half-permeable membranes for inner and outer layers of clothes. Membranes used in experiments were PBT, PTFE, and PU, which were all two layered. Thermal parameters of these membranes like conductivity, diffusion, thermal, and thermal resistance were tested and the results were compared. The best thermal insulation property was detected, respectively, in PBT, PTFE and PU membranes. Bulut and Sülar (9) investigated lamination and coating methods, usage areas of laminated and coated fabrics, production techniques and performance tests. They determined that fabrics produced with coating and lamination methods had different performance and functional properties depending on the type of coating material, technique, textile structure and properties. Bilgi and Kalaoğlu (10) performed a study on performance and comfort properties of military fabrics using special finishing techniques for knitted fabrics made of different raw materials and investigated the effects of these finishing techniques on comfort properties of fabrics. As a result of the experiments, finishing techniques and developed structure of military fabrics were determined to improve comfort properties of fabrics. Güney and Üçgül (11) tested thermal insulation properties of air permeable fabrics made of different materials and layers through Alambeta device and interpreted how these membranes would affect on comfort in the protective cloth by comparing results with graphics. As a result, they concluded that air permeable membranes and porous structures which recently came in use could be effective in improving comfort by allowing heat and water vapor transmissions.

2. MATERIAL AND METHOD

2.1. Material

In this study, lamination was applied to 100% PES raincoat fabrics (ground fabrics) by using hydrophilic breathable PES and PU membranes as well as micro porous PTFE membrane, and the certain comfort properties of the obtained fabrics were investigated. Tests applied to samples were chosen in accordance with the priorities of an enterprise as water impermeability, water repellent, air permeability, and water vapor transmission tests, and lamination was applied in the same enterprise.

Experiments performed with three types of membrane used in this enterprise in line with the study aim were prepared according to the classification given in Table 1. Detailed information about process group in Table 1 is given below.

Water repellent + laminated: Ground fabric was initially subjected to water repellent finishing and then lamination was applied.

Laminated + water repellent: Ground fabrics was initially laminated and then subjected to water repellent finishing.

Table 1. Classification of sample fabrics

Membrane type	Process group	Number of samples
PU	Water repellent+ laminated	2
	Laminated + water repellent	
PES	Water repellent+ laminated	2
	Laminated + water repellent	
PTFE	Water repellent + laminated	2
	Laminated + water repellent	
	Ground fabric (100% PES)	1
Total number of fabrics		7

Ground fabric was subjected to synthetic de-sizing process in the textile finishing department of another enterprise and painted; subsequently, aspect ratio stability was maintained in stenter. Water repellent process table given in Table 2 was prepared based on the pre and post lamination conditions according to data obtained from the enterprise. The aim of the water repellent finishing process was to create a hydrophobic (water repellent) surface around fibers before the pores of fabrics were not completely closed, and thus protect body from water.

Table 2. Parameters of water repellent finishing process (12)

Process parameters		Process stages	
		Water repellent finishing before lamination	Water repellent finishing after lamination
Foulard bath temperature (ºC)		25	25
Fabric passage speed (m/min)		14	14
Foulard wringing pressure (bar)		6	6
Fluorocarbon amount (g/lt)		20	30
Drying stages	Input temperature(ºC)	120	100
	Mid-temperature (ºC)	160	140
	Output temperature (ºC)	180	160
Fabric passage speed (m/dk)		14	14

Table 3. General characteristics of films used in the study (12)

Membrane type	Membrane structure	Thickness (micron)	Weight(g/m^2)	Color
PU	Hydrophilic	20	20	Dull white
PES	Hydrophilic	15	15	Transparent
PTFE	Microporous	35 (±5)	22-25	White

In the study, polyurethane based adhesive matter was used in lamination process applied with hot melting method to fasten membranes and fabrics. Polyurethane adhesives allow the formation of strong viscous bounds on account of their crosswise adherence in humid environment.

100% PES fabrics are among water proof and air permeable fibers produced with modern coating and lamination technology and one of the most used fibers in this technique. Table 4 provides certain information about 100% PES ground fabrics used in the lamination in this study.

2.2. Method

The main classification of the fabrics used in the study is previously given in Table 1. In addition to their physical properties, of ground fabric, laminated fabrics were subjected to water impermeability, water repellent, air permeability and water vapor transmission tests based on the laboratory conditions. Tests performed in the study and standards referred by the enterprise are given in Table 5.

Table 4. Physical characteristics of ground fabric used in the lamination (12)

Fabric Width (cm)		150
Fabric Weight per square meter (g/m²)		115,97
Weave pattern		1/1 plain weave
Density	Weft (1/cm)	31
	Warp (1/cm)	57
Yarn number	Weft (denier)	140
	Warp (denier)	140

3. RESULTS AND DISCUSSION

The experimental results of the laminated fabrics are shown in Table 6. The units and symbols of the performance tests included air permeability, water impermeability and water vapor transmission are listed below.

Table 5. Tests performed on laminated fabrics and relevant standards (13-16)

Tests	Relevant standards
Water impermeability (hydrostatic pressure experiment)	TS 257 EN 20811
Water repellent (spraying method)	TS 259 EN 24920
Air permeability	TS 391 EN ISO 9237
Water vapor transmission	ASTM E 96-00

Table 6. Some comfort properties of the laminated fabrics (12)

Membrane type	Process group	wi	ap	wvt
PU	Water repellent + laminated	537	0,107	1706,97
	Laminated + water repellent	1434,2	0,118	2373,62
PES	Water repellent + laminated	578,4	0,108	2514,44
	Laminated + water repellent	1558,2	0,113	2975,12
PTFE	Water repellent + laminated	1054,2	0,111	3953,24
	Laminated + water repellent	1272,4	0,115	4408,47
Ground fabric (100% PES)		0	51,3	5774,69

wi: water impermeability (cmwg)
ap: air permeability (mm/s)
wvt: water vapor transmission (g/m^2.24h)

The results of water impermeability test in Table 6 demonstrated that laminated experiment sample with PES membrane had better water proofing than other samples. Water impermeability was lower in all membrane groups where water repellent process was previously applied compared to other groups, and this implied that lamination process did not show the expected performance after water repellent finishing was applied. This could be attributed to the fact that water repellent chemical diminished adherence rate of membrane by creating a film layer on fabric surface. Due to the gaps between membrane and fabric, water repellent test results were found lower than those of other groups. Water impermeability test results are graphically given in Figure

1. All membrane groups have high water impermeability in case ground fabrics was initially laminated and then subjected to water repellent finishing, as seen in figure 1.

The results of water repellent test demonstrated that all membrane groups subjected to water repellent finishing process were up to ISO 4 standard (figure 2). Immediate wetting was observed in ground fabric.

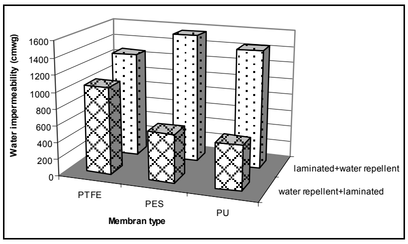

Figure 1. Water impermeability of laminated fabrics

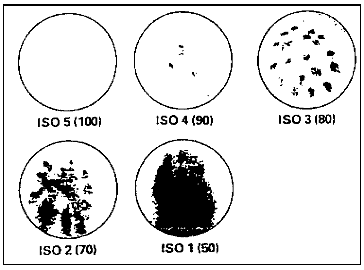

Figure 2. ISO rain-shower

The air permeability test results in Table 6 indicated that the obtained results were low, which was quite normal because PES, PU and PTFE membrane laminations covered pores of ground fabric and prevented air passage. Air permeability was 51.3 mm/s in ground fabric, while it was less than 0.15 mm/s in laminated fabrics. That's because air permeability significantly decreased due to the membrane laminated surface of fabric. This situation is especially important for clothes demanded to have good air permeability. Air permeability test results are graphically given in Figure 3.

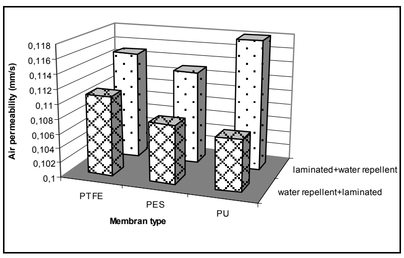

Figure 3. Air permeability of laminated fabrics

The results of water vapor transmission test are given in Table 6 and water vapor test results are graphically given in Figure 4. Test results indicated that laminated fabrics had lower water vapor transmission rates in all three membrane groups compared to those of ground fabric. Fluorocarbon amount in water repellent finishing process applied after lamination was higher than fluorocarbon amounts used in other experiment groups, which possibly did not prevent water vapor transmission much. The higher water vapor transmission of PES membrane group than PU group could be attributed to lower thickness of PES membrane than PU membrane. The closest value to ground fabric was observed in microporous PTFE membrane group. This could be explained by the fact that microporous membrane structures are more suitable to allow water vapor transmission than hydrophilic membrane structures. The reason for the difference between water vapor transmission rates of three membrane groups was attributed to certain factors like the number and size of pores and membrane density. Water vapor transmission results are given in Figure 4, and graphical investigation revealed that PU had the lowest value in each experiment group, while PTFE membrane had the highest score. The different results of membrane groups could be caused by structural differences in membrane materials and membrane types (hydrophilic and microporous).

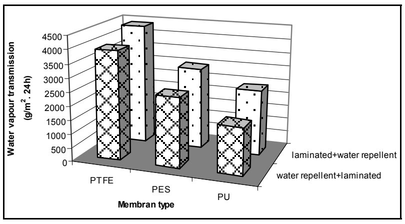

Figure 4. Water vapour transmission of laminated fabrics

SEM Images

SEM image analysis was performed for 6 laminated fabrics. Because membrane parts of samples are not conductive, gold palladium coating was initially made for section, and then 1000x enlarged images with 20 kV voltage were investigated with scanning electron microscope (SEM, Jeol JSM-6390LV model). As can be seen in graphics; air permeability, water impermeability and water vapor transmission were found higher in three membrane groups subjected to water repellent process after lamination than those subjected to water repellent process before lamination. Section images in SEM analysis supported these results (Figure 5-10). Considering the more porous structure of PTFE, pore number, size and densities, sort order of PTFE; PES and PU was supported in water vapor transmission.

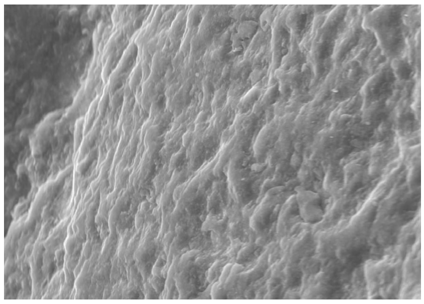

Figure 5. SEM 1 (PTFE Laminated+water repellent)

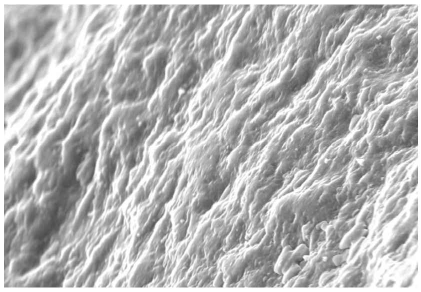

Figure 6. SEM 2 (Water repellent+PTFE Laminated)

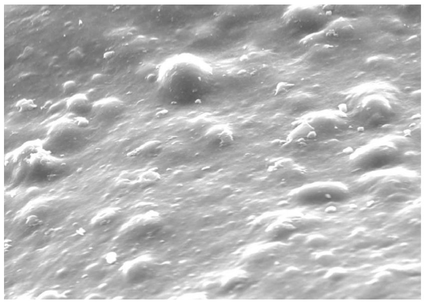

Figure 7. SEM 3 (PU Laminated + water repellent)

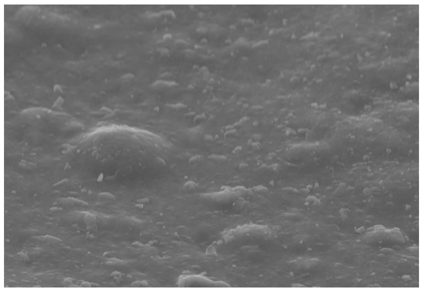

Figure 8. SEM 4 (Water repellent + PU Laminated)

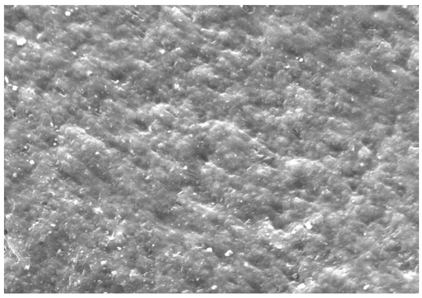

Figure 9. SEM 5 (PES Laminated + water repellent)

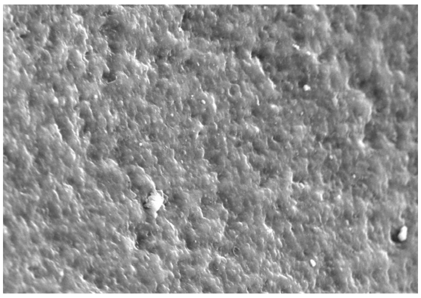

Figure 10. SEM 6 (Water repellent + PES Laminated)

4. CONCLUSIONS

In this study, fabric used in jacket (raincoat) production was laminated with hydrophilic PU and PES and microporous PTFE membrane, and certain comfort properties of samples were tested by certain standards, and the results were graphically interpreted. Lamination groups were composed of lamination after water repellent finishing and lamination before water repellent finishing. Water impermeability, water repellent, air permeability and water vapor transmission were determined by standards related to comfort properties. The obtained results were interpreted with graphics, supported with SEM image analysis and also membrane types were compared.

The results obtained in the study are summarized below:

- ✓ Considering the hydrostatic water proofing values, sample groups subjected to water repellent finishing before lamination had the lowest results than other experiment groups. This could be caused by the fact that water repellent chemical created a film layer on fabric surface and diminished the adhesion rate. Due to the gaps between membrane and fabric, water proofing test results were found lower than those of other groups. When the results were considered in terms of membrane groups, experiment sample laminated with PES membrane had higher water proofing score than other samples.
- ✓ The results of water repellent test indicated that all experiment groups subjected to water repellent finishing were found compatible with ISO 4 standard.
- ✓ Air permeability test results indicated that relatively low scores were quite normal because PES, PU and PTFE membrane lamination closed pores of ground fabric and prevented air flow.
- ✓ Water vapor transmission test results demonstrated that laminated fabrics had lower water vapor transmission rates than ground fabrics in all three membrane groups. The closest score to ground fabric was observed in microporous PTFE membrane group. The different results of membrane groups could be attributed to different materials and membrane types of membranes (hydrophilic and microporous). Microporous membrane structures allow higher water vapor transmission than hydrophilic membrane structures. In addition, the difference in water vapor transmission rates of membranes could also be affected by pore number, size and density in PU, PES and PTFE membranes.

In conclusion, it could be recommended to apply water repellent processes after lamination, in contrast to traditional method using water repellent process prior to lamination.

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