Araştırma Makalesi / ResearchArticle

INVESTIGATION OF VARIOUS SURFACE AND PHYSICAL PROPERTIES OF ACRYLIC COATED WOVEN FABRICS

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ABSTRACT: Acrylic coating is applied to fabrics in order to improve their aesthetic properties as well as their physical performance. In this study, the effects of the acrylic coating process applied to woven fabrics with different structural parameters on various surface (roughness and friction coefficient) and physical performance (permeability and handle) properties of the fabrics were investigated. From the results obtained, a general decrease in the surface roughness parameters and friction coefficients of the fabrics was observed after the acrylic coating process, and these reduction rates were affected by the weave structure of the base fabric and the fabric's structural parameters. A decrease in air permeability, water vapor permeability, and thermal resistance values of acrylic-coated fabrics was observed; in addition, in terms of handle properties, the bending rigidity values increased, and crease recovery angle values decreased.As a result of this study, it was observed that the fabric surfaces after the acrylic coating gained smoother and lower friction coefficient properties, and by taking into account other physical performance properties such as permeability and handle properties of fabrics after coating, it could contribute to the determination of fabric structural parameters to be taken into consideration in the selection of the base fabric to be coated for the desired area of use.

Keywords: Woven fabric, acrylic coating, surface roughness, friction coefficient, permeability, handle.

AKRİLİK KAPLAMALI DOKUMA KUMAŞLARIN ÇEŞİTLİ YÜZEY VE FİZİKSEL ÖZELLİKLERİNİN ARAŞTIRILMASI

ÖZ: Fiziksel performansın yanı sıra estetik özelliklerinde geliştirilmesi amacıyla kumaşlara akrilik kaplama uygulanmaktadır. Bu çalışmada farklı yapısal parametrelere sahip dokuma kumaşlara uygulanana krilik kaplama işleminin kumaşların çeşitli yüzey (pürüzlülük ve sürtünme katsayısı) ve fiziksel performans (geçirgenlik ve tutum) özellikleri üzerindeki etkileri araştırılmıştır. Elde edilen sonuçlardan, genel olarak akrilik kaplama işlemi sonrası kumaşların yüzey pürüzlülük parametrelerinde ve sürtünme katsayılarında azalma gözlenmiş olup, bu azalma oranları taban kumaşın örgü yapısından ve kumaş yapısal parametrelerinde net kilenmiştir. Akrilik kaplamalı kumaşların hava geçirgenliği, subuharıgeçirgenliğiveısıldirençdeğerlerindeazalmagözlemlenirken, tutum özellikleri açısından eğilme rijitliği değerlerinde artış, katlanmadan sonra geri gelme açısı değerlerinde azalma gözlenmiştir. Bu çalışma sonucunda, akrilik kaplama sonrası kumaş yüzeylerinin daha pürüzsüz ve daha düşük sürtünme katsayısı özelliği kazandığı gözlemlenmiş olup, kaplama sonrası kumaşların geçirgenlik ve tutum özellikleri gibi diğer fiziksel performans özelliklerinin de dikkate alınmasıyla, istenilen kullanımalanı için kaplanacak taban kumaş seçiminde dik kate alınacak yapısal parametrelerin belirlenmesine katkı sağlayabileceği ön görülmüştür.

AnahtarKelimeler: Dokuma kumaş, akrilik kaplama, yüzey pürüzlülüğü, sürtünme katsayısı, geçirgenlik, tutum.

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1. INTRODUCTION

Woven fabrics are textile structures formed by the intersection of two perpendicular yarn systems, called warp and weft, in various positions depending on the weave pattern structure. The structural parameters of woven fabrics, raw material properties, yarn structural properties, fabric structural properties, and various processes that the fabrics undergo after the weaving process determine various characteristic features of the fabrics, such as physical performance and appearance. Therefore, it is essential to decide on these parameters according to the purpose and usage areas in the design of the fabrics.

The coating process is one of the production methods used to improve textile products' technical performance and functional properties, rather than their improved appearance and aesthetic properties. The performance and functional properties of fabrics vary according to the coating material used, the technique applied, and the structure and properties of the textile surface [1].Acrylic, polyvinyl chloride, polyvinyl alcohol, polyurethane, silicone, epoxy resin, and polyester are some polymeric materials used in coating processes. In the coating process, such as immersion, knife, transfer, gravure roll, and screen coating are used in coating methods [2-5].While the base fabric structure on which the coating process is applied affects various physical properties such as breaking strength, tearing, and elongation in the final product, the coating material provides properties such as fabric porosity, protection of the fabric from chemical and environmental effects, and, in some cases, appearance improvement [6]. In addition to selectingthe base fabric and coating material to be coated, the coating method to be applied determines the performance characteristics of the final product. The coating material should have a viscosity that will allow it to spread on the fiber and yarn surfaces, and the fabric surface should be flat and smooth after coating. In the knife coating (squeegee coating) method, where the coating material is dosed later, the coating material is directly transferred to the fabric and applied uniformly with a fixed knife. It is usually applied to smooth, uniform woven fabrics [1].Polyester can be preferred in base fabrics where the coating process is applied due to its advantageous properties, such as heat resistance, low shrinkage, and high abrasion resistance [7].Acrylic polymers are transparent-colored and highly stable polymers[8]. It is stated that acrylic coatings help to increase the fabric's durability, UV resistance, and resistance to fading of the fabric, and that they have advantages such as being suitable for humid environments since they are generally resistant to mold and mildew formation. In addition, it is stated that acrylic coatings offer a certain level of water resistance and may affect material flexibility and drape behavior due to their hardening effect [9].

In a study [10] where different ratios of acrylic coating are applied to polyester roller blind fabrics, it is stated that air permeability decreased and water resistance increased up to a certain limit as the acrylic ratio increased as a result of the closure of the pores with acrylic material. As the acrylic ratio increases, the coating material becomes brittle and moves away from the pores under the influence of air and water pressure, thus increasing air permeability and decreasing the fabric's water resistance. It is stated that after the coating process, the breaking strength of the fabrics falls below the values before coating, and the values fall further as the acrylic ratio increases. This decrease in the breaking strength values is observed due to the decreased yarn-yarn friction after the coating process.

In a study [11] in which acrylic foam coating at different coating rates was applied to polyester upholstery fabrics woven with different weft density values, it is stated that the air permeability values of the fabrics decreased as the weft density and coating rate of the fabric increased.

A study on the effect of ethylene acrylic acid co-polymer coating on the bending and thermal properties of cotton fabrics [12] states that it produces a stiffer feel and increased bending rigidity values of the fabrics. It is also noted that the coated fabrics are thermally stable and have good surface properties.

Studies in the literature examine the surface properties of fabrics coated with different coating materials.In a study [13] investigating the effect of polyurethane coating on the surface roughness of woven fabrics with different properties, coating parameters such as curing temperature, gap spacing, coating speed and viscosity of the coating paste are tested. It is stated that coatings with low roughness could be obtained by selecting appropriate process parameters in the coating process. It is stated that fabric type and microstructure are the main determining factors ofsurface roughness.In a study [14] examining the surface roughness and friction coefficient values of plain weave polyester fabrics coated with graphene at different concentrations (5%, 10% and 20%), it is stated that the coating concentration affects the friction and surface roughness properties of the fabrics, and the fabric surface roughness and friction coefficient values decrease significantly, especially at 20% concentration.In a study [15] examining the effects of different weave structures (basket, twill, and sateen) used in the base fabric on various surface roughness parameters of calcite coated polyester fabrics, it is stated that the surface roughness values vary depending on the pattern of the base fabric, warp and weft directions and weft yarn density of fabrics and that in general, after the coating process, surface roughness values of the fabrics decrease in both weft and warp directions.

There are studies in the literature indicating that multifunctional properties are imparted to fabrics through acrylic coating processes enriched with functional additives. A survey on cotton fabrics coated with polyacrylate polymers containing various iron ores [16] indicated that iron ore coatings could yield cotton fabrics with multifunctional properties such as flame retardancy, UV protection, and antibacterial properties, as well as natural coloration. Also, it is stated that the air permeability and tear strength values of iron ore-coated fabrics decreased while their abrasion resistance improved compared to untreated cotton fabric.

A study on cotton fabrics coated with an acrylate-based polymer paste containing huntite-hydromagnesite [17]states that it improves the flame retardancy and antibacterial properties of fabrics. Furthermore, it is stated that the maximum abrasion cycles after the coating process are significantly increased, and colorimetric properties such as whiteness and lightness of fabrics are not significantly change after the coating process.

A study investigating the effects of self-crosslinking acrylate with TiO_2 nanoparticles on cotton denim fabrics [18],states that improving abrasion resistance and self-cleaning properties in denim fabrics can be achieved with the optimum amount of self-crosslinking acrylate and the appropriate pH level. Also, it is noted that this coating process reduces the air permeability and softness of denim fabrics.

Coating processes are generally applied to fabrics to improve their various performance properties. Acrylic coatings are applied to fabrics to improve physical performance properties such as protective barrier properties (e.g. UV protective, waterproof, abrasion and wear resistance, etc.) and aesthetic properties such as surface smoothing and different surface appearance (e.g. transparent, semi-dull or glossy),and it has a wide application area in the sector.

For this purpose, the aim was to evaluate how the performance properties of acrylic-coated fabrics applied to improve various performance properties were affected by the structural parameters of the base fabric. Especially, the effects of the structural parameters forming the base fabric on various performance properties of the coated fabrics were evaluated. The changes in surface (roughness and friction) andvarious performance (permeability and handle) properties of woven fabrics with different structural parameters after acrylic coating were examined, and the effects of the base fabric structure on these examined properties were evaluated.As a result of this study, it was anticipated that it would contribute to the determination of the base fabric type to be selected for coating for the desired usage area and the structural parameters of the base fabric.

2. MATERIAL AND METHOD

The constructional parameters of uncoated base polyester fabrics and acrylic-coated fabric used in the study are presented in Table 1. Uncoated and coated fabric samples were provided by AKPA TeknikKaplama (Bursa/Türkiye). It was stated that the chemicals used in the acrylic coating paste consist of binder, synthetic thickener, crosslinking agents, anti-foam agent, ammonia, and the acrylic coating applied to the fabrics was made according to the knife-over-roll method on the TEXTIMA 96 model coating machine. It was stated that the drying temperature was 170 ^{o}C at the inlet, 180 ^{o}C at the outlet, and the drying time was 1 minute on average. After the coating, it was stated that the fabrics go through the calendering process, which was carried out on a GÜÇLÜPOL brand calender machine under 30 tons of pressure and at a working speed of 30 m/min.

When Table 1 was examined, it was seen that although the fabric mass per unit area values of the fabrics increased as expected after the coating process, the fabric thickness values decreased. It was thought that this decrease in fabric thickness was due to the calendering process applied to the fabrics after the coating process.

As it is known, the calendering is a finishing process in which the fabric passes between two or more cylinders under a certain temperature and pressure to change its properties, such as handle, surface texture, and appearance. The calendering process tends to reduce fabric thickness and air permeability, and increase smoothness and brightness [19].

The images of the fabrics under the digital microscope (Dino-Lite) (30 times magnification) are presented in Figure 1.

2.1. Surface roughness

Arithmetic average height (R_a) can be defined as the absolute deviation of the roughness irregularities from the mean line along the length of a sample. This parameter gives a general description of the height changes in the profile. Mean height of peaks (R_{pm}) and mean depth of valleys (R_{vm}) can be defined as the average of the maximum height of the peaks and maximum depth of the valleys for each sampling length, respectively. Mean slope of the profile (Δ_a) can be defined as the average absolute profile slope along the evaluation length. This parameter can be calculated by calculating all slopes between every two consecutive points of the profile and then averaging the results of these slopes [20].

Table 1. Structural properties of uncoated and coated fabrics

Fabric Code	Yarn Count [Denier]		Yarn Density [threads/cm]		Fabric Thickness* [mm]			Fabric Mass per Unit Area [g/m^2]			Weave Pattern
	Warp	Weft	Warp	Weft	Uncoated	Coated	% decrease	Uncoated	Coated	% increase	
Plain-I	120	171	36	16	0.22	0.17	22.73	62.8	67	6.69	Plain
Plain-II	317.23	306.01	22	20	0.28	0.12	57.14	132.4	148.5	12.16	Plain
Herringbone	350	316.68	24	18	0.48	0.34	29.17	156.4	179	14.45	Twill
Jacquard-I	81.00	135.14	63	19	0.19	0.16	15.79	89	132	48.31	Jacquard (stripe pattern)
Jacquard-II	233.77	270.27	23	21	0.21	0.14	33.33	91.1	141.1	54.88	Jacquard (square pattern)

**Thickness values were taken from the "h" values measured by the Alembeta test device.*

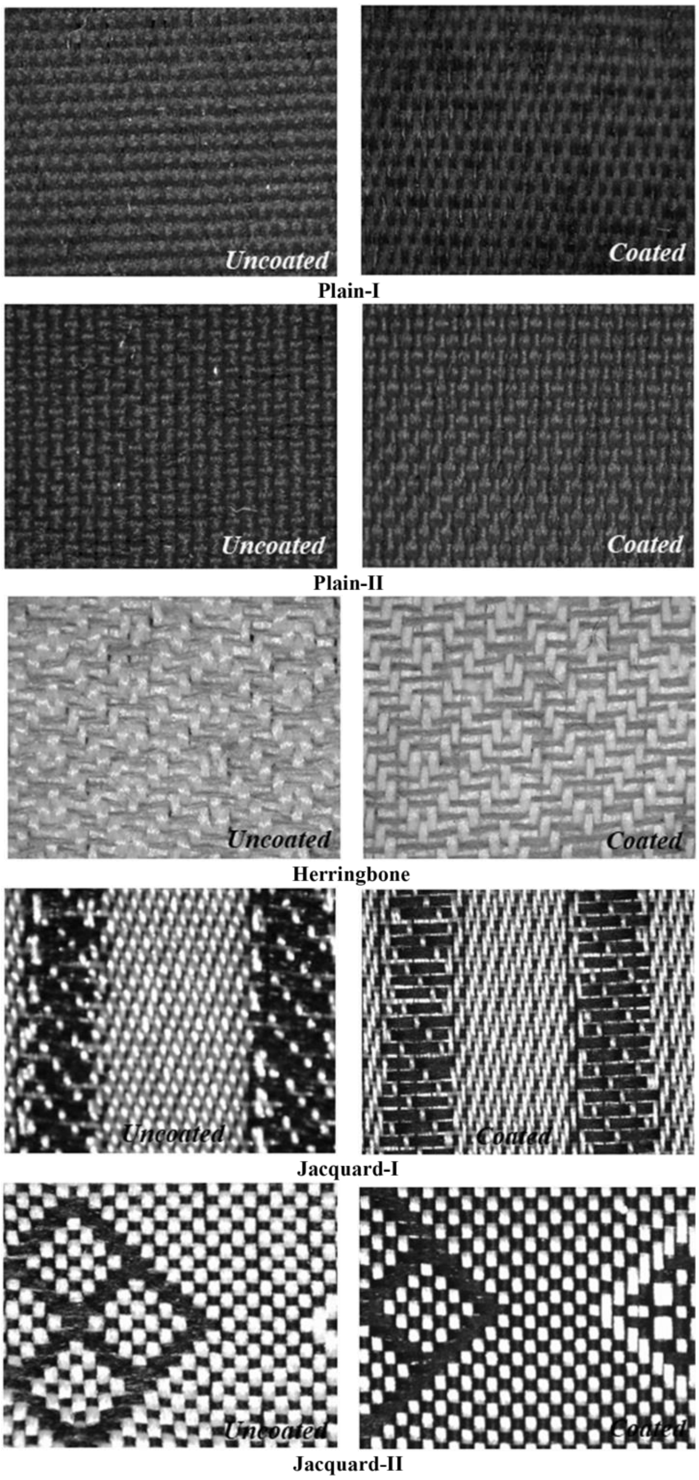


Figure 1. Microscope images of fabrics (Mag: 30X)

Various surface roughness parameters of the fabrics (Arithmetic average height (R_a), Mean height of peaks (R_{pm}), Mean depth of valleys (R_{vm}), Mean slope of the profile (Δ_a)) were measured in the warp and weft directions with the Surfcom 130A surface roughness tester (Figure 2) by the ISO 21920-2:2021 standard. Surface roughness measurement parameters were performed at a measurement speed of 1.5 mm/s, an evaluation length of 50 mm, and a cut-off value of 0.8 mm.

Figure 2. Surface Roughness Tester (Surfcom 130 A)

2.2. Surface friction coefficient

Friction force is the force that resists the movement of two material surfaces in opposition to each other. The ratio of the friction force (F) to the normal force (N) between two surfaces is defined as the friction coefficient ($\mu=F/N$) and is a dimensionless value. The static friction coefficient (μ_s) is the ratio between the maximum value of the friction force and the normal force, while the dynamic (kinetic) friction coefficient (μ_d) is the ratio between the friction force and the normal force in motion. In general, for the same material, $\mu_s>\mu_d$[21].

The static (μ_s) and dynamic (μ_d) friction coefficients of the fabrics were measured on the LabthinkParam MXD-02 friction tester (Figure 3) according to the ASTM D 1894 standard. The friction coefficients of the uncoated and coated fabrics were measured using a standard abrasive wool fabric (ASTM D 4966) to keep the material the fabric samples rub against fixed. The tested fabric sample was mounted on the upper slide (mass of the slide: 200 g), and the standard abrasive wool fabric was mounted on the lower moving plate (test speed: 150 mm/min; measurement length: 150 mm) of the friction coefficient tester. The friction coefficient measurements of the fabric samples were made in the warp and weft directions.

Figure 3. Friction coefficient tester (LabthinkParam MXD-02)

2.3 Air permeability

The air permeability of fabrics was measured according to EN ISO 9237 (1995) standardusing SDL Atlas M 021A digital air permeability tester. Measurements were performed by applying 100 Pa air pressure per 100 cm^2 fabric surface area.

2.4 Relative water vapor permeability

Relative water vapor permeability was measured on a Permetest instrument according to the ISO 11092 standard.

2.5 Thermal resistance (r)

Thermal resistance is defined as the resistance of the material to heat flow. The thermal resistance of the fabrics was measured using the Alambeta tester. The thermal resistance related to the fabric thickness and thermal conductivity coefficient was calculated using Equation (1) [22].

$$r = h / \lambda \ (m^2K/W) \quad (1)$$

where, r: thermal resistance, h: fabric thickness (m), λ: thermal conductivity coefficient (W/mK).

2.6. Bending rigidity

The bending rigidity of fabrics was measured according to ASTM 1388-96 (2002) standard using an SDL Atlas fabric stiffness tester. The bending rigidities in the warp and weft directions were calculated using Equation (2):

$$G = W \ x \ c^3 \quad (2)$$

where G is the bending rigidity (mgcm), W is the mass per unit area (mg/cm^2), and the bending length c is equal to half the length of the overhang (cm).

Equation (3) was used to calculate the overall fabric bending rigidity:

$$G_o = (G_w \ x \ G_f)^{1/2} \quad (3)$$

where G_o is the overall fabric bending rigidity (mgcm), G_w is the warp bending rigidity (mgcm), and G_f is the weft bending rigidity (mgcm).

2.7 Crease recovery angle

The SDL Atlas crease recovery test device was employed to measure the recovery from creasing of a horizontally folded specimen by measuring the angle of recovery of fabric samples according to the TS 390 EN 22313 standard test method. The fabrics were kept under a load of 10 N for 5 min ± 5 s, and the crease recovery angle was measured 5 minutes after the pressure was removed from the folded test sample. In evaluating the crease recovery angles of the fabrics, the crease recovery angles of the samples taken in the warp and weft directions were tested, and the crease recovery angle of the fabric was evaluated by taking the average values of the warp and weft direction measurements.

In all tests, three measurements were taken from each fabric sample (three from each direction in tests where the fabric direction was also taken into account), and average values were used to evaluate the results.

2.8 Statistical analysis

The t-test was performed to compare the means of uncoated and coated samples, with a significance level (α) set at 0.05. Probability (p) values were calculated to assess the significance of the results. Also, standard deviation ranges of the test results were calculated. SPSS statistical program was used.

3. RESULTS AND DISCUSSION

3.1. Evaluation of surface roughness and friction coefficients

To evaluate the surface properties of fabrics after the coating process, the various surface roughness parameters and friction coefficients of fabrics were examined. Figure 4presents the arithmetic average height (R_a) values in the warp and weft directions of the uncoated and acrylic-coated fabric surfaces. The standard deviation ranges for uncoated fabrics' warp and weft directional R_a test results were ≈ 0.33 – 1.06 and 0.15 – 0.45, respectively. The standard deviation ranges for coated fabrics' warp and weft directional R_a test results were ≈ 0.10 – 0.45 and 0.09 – 0.78, respectively.

Figure 4, the R_a values decreased after the acrylic coating process in all the examined fabrics. The % decrease in R_a values after the coating process is shown in the graph in Figure 4.

When the changes in the R_a values of the fabrics were examined in Figure 4, R_a values in the warp and weft directions of the fabrics with plain and jacquard weave structures decrease significantly after the coating process. When the surface roughness of the herringbone coded fabric was examined, the decrease rate in R_a values after the coating process was relatively low. It was observed that the amount of change in the fabric Ra value after the coating process might vary depending on the surface texture of the base fabric. This result might be due to the effect of the weave structure of the base fabric of the coating process on the R_{pm} and R_{vm} values of the fabric surface, as seen from the R_{pm} and R_{vm} values of the fabric surfaces presented below.

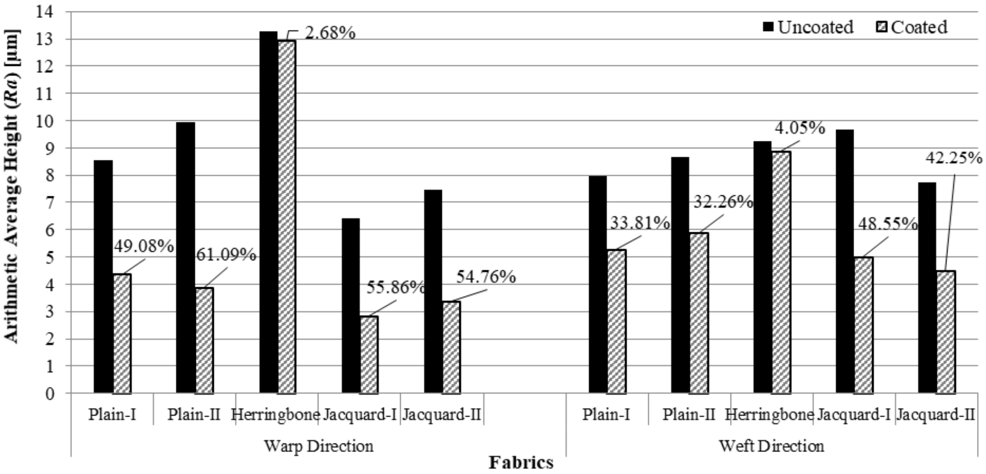


Figure 4. Arithmetic average height (R_a) values of fabrics

Figures 5 and 6 present the mean height of peaks (R_{pm}) and the mean depth of valleys (R_{vm}) values in the warp and weft directions of the uncoated and acrylic-coated fabric surfaces, respectively. The standard deviation rangesfor uncoated fabrics' warpand weft directional R_{pm} test results were ≈ 0.42 – 1.59 and 0.23 – 0.96, respectively. The standard deviation ranges for coated fabrics' warp and weft directional R_{pm} test results were ≈ 0.16 – 1.91 and 0.00 – 0.88, respectively. The standard deviation ranges foruncoated fabrics' warp and weft directional R_{vm} test results were ≈ 0.38 – 0.77 and 0.00 – 0.96, respectively. The standard deviation ranges for coated fabrics' warp and weft directional R_{vm} test results were ≈ 0.04 – 0.87 and 0.36 – 0.90, respectively.

When the changes in the R_{pm} and R_{vm} values of the fabrics were examined in Figures 5 and 6, there was a significant decrease in the R_{pm} and R_{vm} values in the warp and weft directions of the fabrics woven with plain and jacquard weave structures after the coating process. It was seen that the decrease rate in the R_{pm} value in the herringbone base fabric structure was quite less than that of other fabrics. When the R_{vm} value of the herringbone base fabric was examined, an increase in the warp direction R_{vm} value and a slight decrease in the weft direction R_{vm} value were observed.

It was thought that these different trends observed in the surface roughness values in the warp and weft directions after the coating process in the fabric woven with herringbone weave structure might be due to the float lengths of the yarns in the twill weave structure (Figure 1) forming the base fabric, the thickness and density values of the yarns forming the fabric and depending on these parameters the effect of the indentations and protrusions on the fabric surface.

Figure 7 presents the mean slope of the profile (Δa) values in the warp and weft directions of the uncoated and acrylic-coated fabric surfaces. The standard deviation ranges for uncoated fabrics' warp and weft directional Δa test results were ≈ 0.00 – 0.03 and 0.00 – 0.02, respectively. The standard deviation ranges for coated fabrics' warp and weft directional Δa test results were ≈ 0.00 – 0.02 and 0.00 – 0.02, respectively.

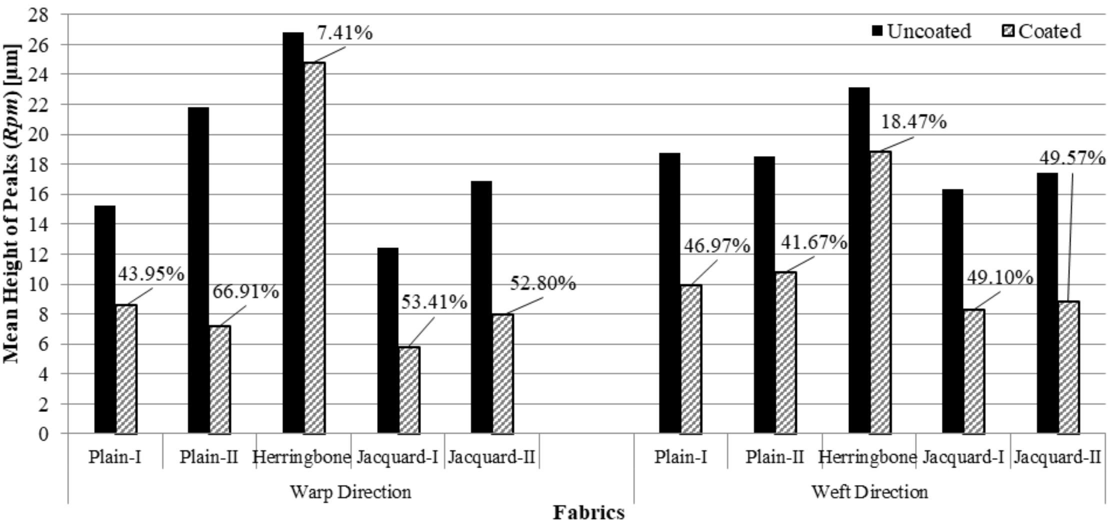


Figure 5. Mean height of peaks (R_{pm}) values of fabrics

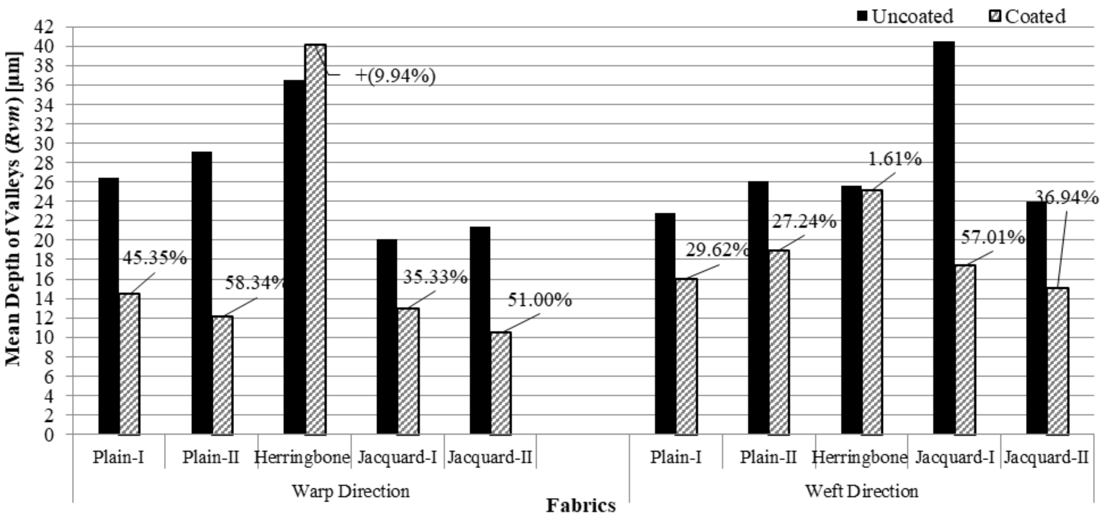


Figure 6. Mean depth of valleys (R_{vm}) values of fabrics

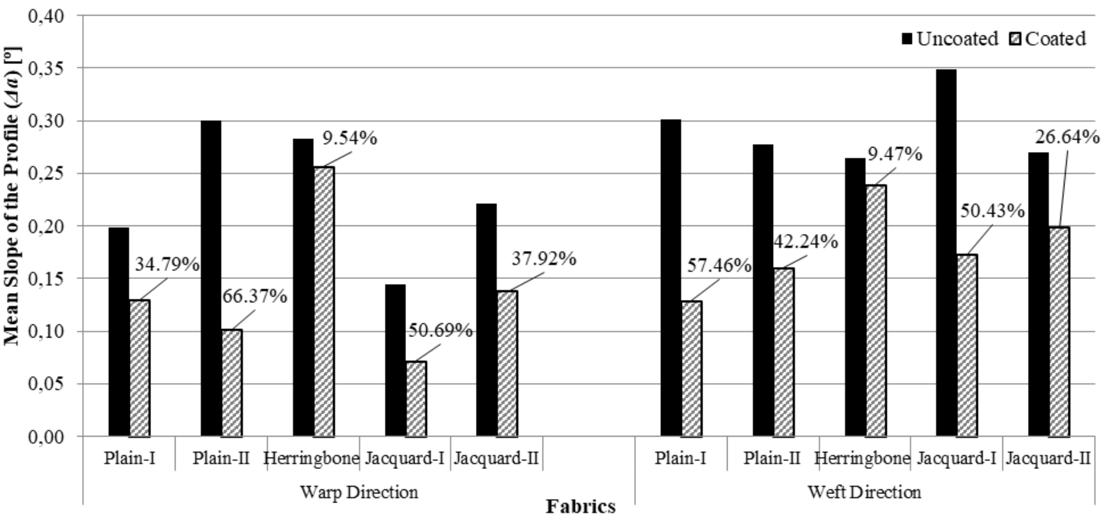


Figure 7. Mean slope of the profile (*Δa*) values of fabrics

Figure 7 shows that the mean slope of the profile (*Δa*) of all fabric surfaces decreases after the coating process. The decrease rates in the *Δa* values of the fabric surfaces after the coating process were high in plain and jacquard base fabrics, while the decrease in this *Δa* value was relatively low in the herringbone base structured fabric.

When the changes in the surface roughness values of the fabrics after the coating process were examined, there was a general decrease in the surface roughness parameters after the coating process, and the amount of this decrease was affected by the base fabric structure.

Friction coefficient values of fabrics at warp and weft directions are presented in Figures 8 and 9, respectively. To evaluate the comparisons in the coefficient of friction tests, the other surface where all fabrics rubbed in the fabric-fabric friction was kept constant. For this purpose, woolen woven fabric was used as the opposite surface in the measurement of the coefficients of friction of the fabrics, and the tests were carried out by placing the woolen fabric on the lower floor of the test device and the test samples on the upper slide (Figure 3).

The standard deviation ranges for uncoated fabrics' warp and weft directional μ_s test results were ≈ 0.00 – 0.05 and 0.00 – 0.02, respectively. The standard deviation ranges for coated fabrics' warp and weft directional μ_s test results were ≈ 0.00 – 0.01 and 0.00 – 0.01, respectively. The standard deviation ranges for uncoated fabrics' warp and weft directional μ_d test results were ≈ 0.00 – 0.01 and 0.00 – 0.02, respectively. The standard deviation ranges for coated fabrics' warp and weft directional μ_d test results were ≈ 0.00 – 0.01 and 0.00 – 0.01, respectively.

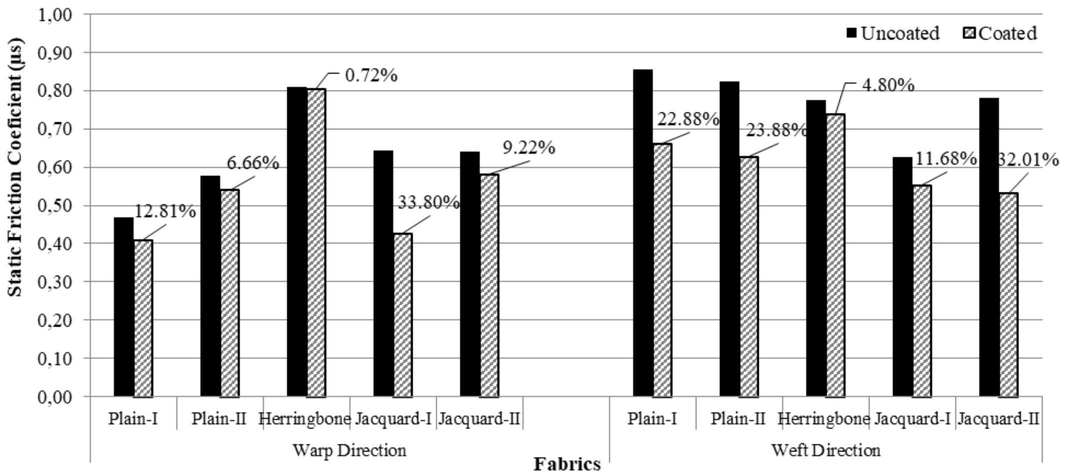


Figure 8. Static friction coefficients (μ_s) of fabrics

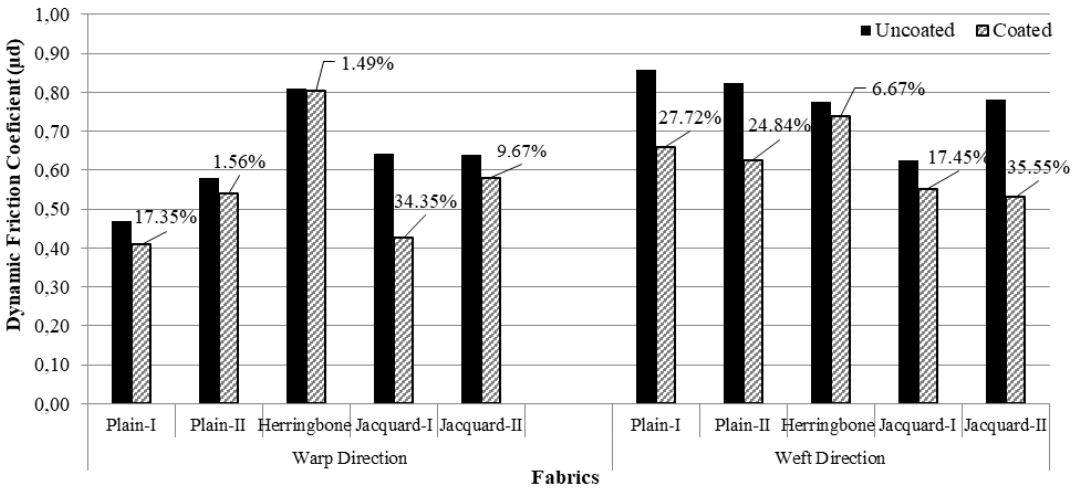


Figure 9. Dynamic friction coefficients (μ_d) of fabrics

In Figures 8 and 9, a decrease in the friction coefficient values of the fabrics after the coating process was observed, and the different reduction rates were affected by the structure of the base fabric. The lowest decrease in the friction coefficient value after coating was seen in the base fabric with herringbone coded twill weave structure.

The decrease in the friction coefficient values was high, especially in the jacquard structured large patterned fabric structure after the coating process. The surface texture effect, which could cause different variations due to the effect of the weave used in the patterning of jacquard structured fabrics and the floats and intersections made by the yarns on the fabric surface, caused a high decrease in the friction coefficient of the fabric with such a structure after the coating process, as a result of the fabric surface creating a more homogeneous and smooth surface after the coating.

In base fabrics woven with plain weave, the decrease in the friction coefficient values in the weft direction after the coating process was higher than in the warp direction.

The t-test results for surface roughness and friction coefficient of the fabrics in the uncoated and coated state are presented in Tables 2 and 3, respectively. The p-values less than the significance level (α = 0.05) in these tables indicate a significant difference in results.

3.2. Evaluation of air permeability, relative water vapour permeability, and thermal resistance

To evaluate the permeability and thermal properties of fabrics before and after the coating process, the air permeability, relative water vapour permeability, and thermal resistance of fabrics were examined. Air permeability values of uncoated and coated fabrics are presented in Figure 10. The standard deviation ranges of uncoated and coated fabrics'air permeability test results were ≈ 0.71 – 1.41 and 0.02 – 0.78, respectively.

Table 2. T-test results for surface roughness of the fabrics in the uncoated and coated state

		p-values			
		Arithmetic average height (R_a)	Mean height of peaks (R_{pm})	Mean depth of valleys (R_{vm})	Mean slope of the profile (Δa)
Warp Direction	Plain-I	0.0003*	0.0106*	0.0063*	0.0043*
	Plain-II	0.0082*	0.0089*	0.0041*	0.0097*
	Herringbone	0.1242	0.2904	0.0612	0.1928
	Jacquard-I	0.0111*	0.0027*	0.0012*	0.0170*
	Jacquard-II	0.0214*	0.0277*	0.0089*	0.0025*
Weft Direction	Plain-I	0.0278*	0.0149*	0.0042*	0.0011*
	Plain-II	0.0323*	0.0368*	0.0014*	0.0104*
	Herringbone	0.2554	0.0158*	0.1629	0.2174
	Jacquard-I	0.0264*	0.0031*	0.0000*	0.0047*
	Jacquard-II	0.0008*	0.0004*	0.0037*	0.0159*

**significant difference*

Table 3. T-test results for the friction coefficient of the fabrics in the uncoated and coated state

		p-values	
		Static friction coefficients (μ_s)	Dynamic friction coefficients (μ_d)
Warp Direction	Plain-I	0.0007*	0.0070*
	Plain-II	0.0456*	0.0387*
	Herringbone	0.4003	0.1252
	Jacquard-I	0.0002*	0.0007*
	Jacquard-II	0.0175*	0.0272*
Weft Direction	Plain-I	0.0020*	0.0019*
	Plain-II	0.0008*	0.0002*
	Herringbone	0.0621	0.0415*
	Jacquard-I	0.0005*	0.0024*
	Jacquard-II	0.0010*	0.0006*

**significant difference*

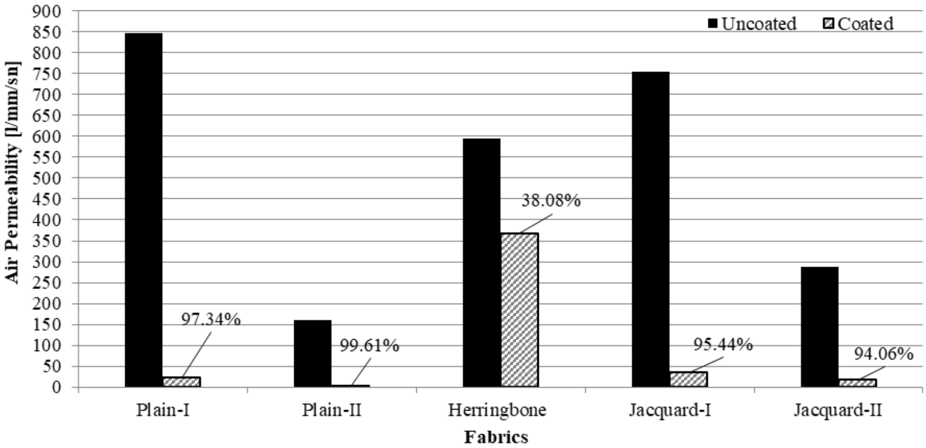


Figure 10. Air permeability of fabrics

In Figure 10, the air permeability of acrylic-coated fabrics decreased. The % decrease in air permeability values of the fabrics after the coating process is shown in the graph in Figure 1. It was observed that this decrease was at quite high rates, especially in fabric constructions woven in plain and jacquard weave structures (due to the effect of the yarn thickness and density that form the fabric structure, as well as the weave structure). The air permeability of the herringbone base fabric with twill weave pattern construction after coating decreased less than that of other fabric constructions. It was thought that the weave structure that forms the base fabric with twill might affect this result (due to the effect of long yarn floats in the weave structure), as well as the yarn thickness (due to the effect of thick yarn) and yarn density (due to the effect of low yarn density) values that form the fabric construction.

From the results obtained, it was observed that the air permeability of the fabrics decreased after the acrylic coating and this decrease rate was affected by the structural parameters that make up the fabric. For this purpose, in the fabric structures where the coating process would be applied, it could be foreseen that the fabric constructions that could be preferred depending on the place of use could be selected accordingly in cases where the air permeability of the coating process was desired to be reduced.

Relative water vapour permeability values of uncoated and coated fabrics are presented in Figure 11.The standard deviation rangesof uncoated and coated fabrics' water vapor permeability test results were ≈ 0.23 – 3.54 and 0.01 – 2.19, respectively.

In Figure 11, the water vapor permeability of the fabrics decreased after the acrylic coating process. In plain fabrics, it was seen that the decrease in the plain-II coded fabric was higher than the Palin-I coded fabric. When Table 1 was examined, this result might be due to the lowest increase in the fabric mass per unit area value of the plain-I coded fabric after the coating process. It was observed that the increase in fabric mass per unit area values of other fabrics after the coating process was higher.

When the air permeability values were examined (Figure 10), it was observed that although the decrease rates in the air permeability values of the Plain-I and Plain-II coded fabrics after coating were approximately similar, the trend in water vapor permeability was different. This situation could be because the amount of change in the fabric mass per unit area values after the coating process affects the water vapor permeability value of the fabric. In other words, it was considered that the coating rate that the fabric received after coating could be a more effective factor, especially on the water vapor permeability of the fabric. Similarly, the decrease in water vapor permeability values was high in jacquard coded fabrics after coating, and also it was seen from Table 1 that the increase in fabric mass per unit area values of jacquard coded fabrics after coating was high.

In the herringbone coded fabric structure, it was observed that the water vapor permeability value decreased after the coating process, and this decreasing trend was low, as in the air permeability. Although the increase in the fabric mass per unit area values after coating in the herringbone fabric was close to the plain-II coded fabric, it was thought that the reason for the low decrease in the water vapor value of this fabric might be the effect of the twill weave structure forming the base fabric (due to the effect of long yarn floats in the weave structure), as well as the effects of the yarn thickness (due to the effect of thick yarn) and yarn density (due to the effect of low yarn density) values forming the fabric construction.

Thermal resistance (r) values of fabrics are presented in Figure 12. The standard deviation rangesof uncoated and coated fabrics' thermal resistance (r) test results were ≈ 0.09 – 0.30 and 0.10 – 0.16, respectively.

In Figure 12, it was seen that the thermal resistance values of the fabrics decrease after the acrylic coating process.

The decrease in the thermal resistance values of fabrics after the coating process might be due to the amount of air in the fabric structure. Stagnant air is an ideal insulation material since the thermal conductivity of stagnant air is lower than that of all fibers. Therefore, a textile material that requires high thermal insulation must contain much air in its internal structure. As the amount of stagnant air in the material increases, the thermal resistance of the material also increases [23,24]. Therefore, if it was considered that the pores between the yarns and also fibers in the fabric structure, where stagnant air could be found, were also filled with the coating material, since stagnant air could not be stored in the fabric structure, it was observed that the thermal resistance of the fabrics after the coating process also decreased.

In Figure 12, when the thermal resistance values of the uncoated fabrics were examined, the base fabric structure with the highest thermal resistance was the herringbone coded fabric. As seen from Table 1, the high fabric thickness and fabric mass per unit area values of the herringbone coded fabric affected this result. The high amount of stagnant air that a bulky and thick fabric structure would contain increases the thermal resistance value of this fabric structure. It was also seen that the decrease in the thermal resistance value was the highest in this fabric structure after the coating process.

The t-test results for air permeability, relative water vapor permeability, and thermal resistance of the fabrics in the uncoated and coated state are presented in Table4. The p-values less than the significance level (α = 0.05) in these tables indicate a significant difference in results.

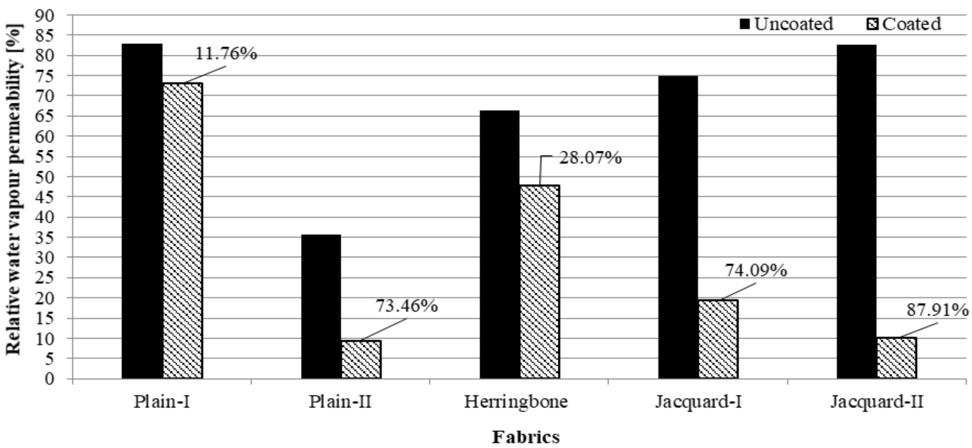


Figure 11. Relative water vapor permeability values of fabrics

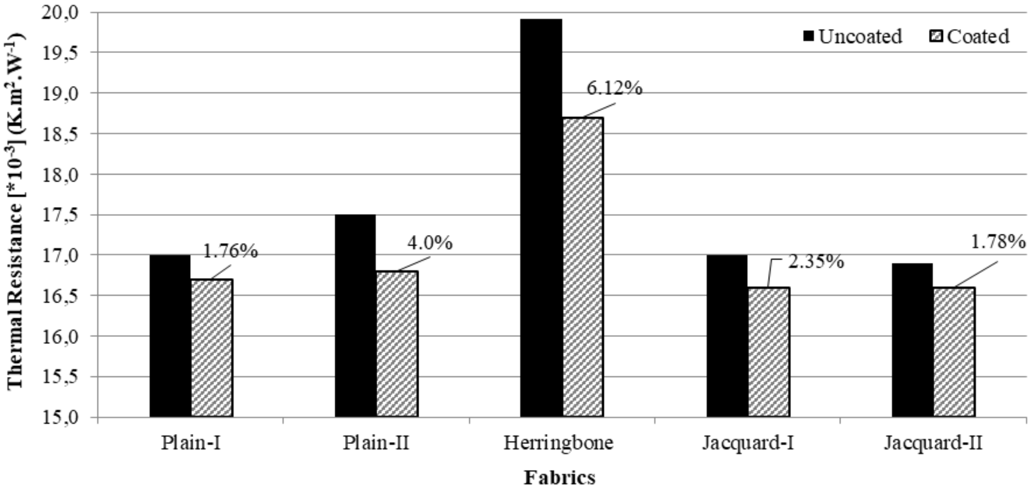


Figure 12. Thermal resistance (r) values of fabrics

Table 4. T-test results for air permeability, relative water vapor permeability, and thermal resistance of the fabrics in the uncoated and coated state

	p-values		
	Air permeability	Water vapor permeability	Thermal resistance (r)
Plain-I	0.0000*	0.0047*	0.0006*
Plain-II	0.0000*	0.0097*	0.0045*
Herringbone	0.0000*	0.0072*	0.0004*
Jacquard-I	0.0000*	0.0004*	0.0004*
Jacquard-II	0.0000*	0.0017*	0.0058*

**significant difference*

3.3. Evaluation of bending rigidity and crease recovery angle

To evaluate the physical performance properties, such as handle, hardness, etc., of fabrics before and after the coating processes, the bending rigidity (Figure13) and crease recovery angle (Figure 14) were examined.

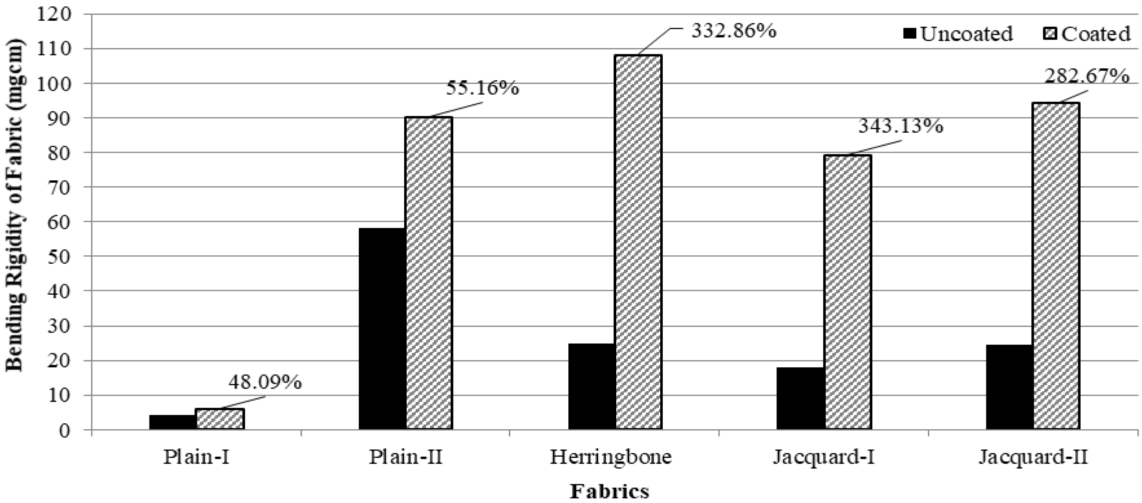
Bending rigidity values of uncoated and coated fabrics are presented in Figure 13.Figure 13 presents the general fabric bending rigidity (Equation (3)) values calculated from the warp and weft bending rigidities of the fabrics. The standard deviation ranges of uncoated and coated fabrics' bending rigidity test results were ≈ 0.27 – 0.60 and 0.21 – 0.62, respectively.

In Figure 13, the bending rigidity values of the fabrics increased significantly after the acrylic coating process. It was thought that this result was due to the hardness effect that the acrylic coating process gave to the fabric, as could be felt from the fabric's hand feel. In addition, as seen from the increase in bending rigidity after coating in Figure 13, the effect of the base fabric structural parameters and the coating rate received by the fabric also affected the bending rigidity of the fabric after coating. In plain structured fabrics, the increase in the bending rigidity value of the plain-II coded fabric after coating was higher than that of the plain-I fabric. It was thought that this result was affected by the effect of the weight values of the fabrics in the uncoated state (because a low-weight structure has a lower bending rigidity than a high-weight structure) as well as the lower increase in the fabric mass per unit area ratio after coating (in other words, because the fabric receives less coating material after coating).

Crease recovery angle values of uncoated and coated fabrics are presented in Figure 14.The standard deviation ranges of uncoated and coated fabrics' crease recovery angle test results were ≈ 0.29 – 2.83 and 0.71 – 2.12, respectively.

Figure 14 presents the fabric crease recovery angles calculated by taking the average of the warp and weft crease recovery angles of the fabrics. The crease recovery angle indicates the state of the fabric returning after folding. The greater the return angle value after folding (approaching 180^o), the faster the fabric can return to its original state.

The experimental results showed thatthe crease recovery angles of the fabrics decreased after the coating process; in other words, it became difficult to return to their initial state after folding. It should be noted that the ability to return after folding could also be affected by the uncoated base fabric construction. As seen in the plain-I coded fabric, the ability to return after coating was the least in this fabric structure. From Table 1, the plain-I fabric had the lowest mass per unit area, which might affect the fabric's ability to return after folding.



Figures 13. Bending rigidity of fabrics

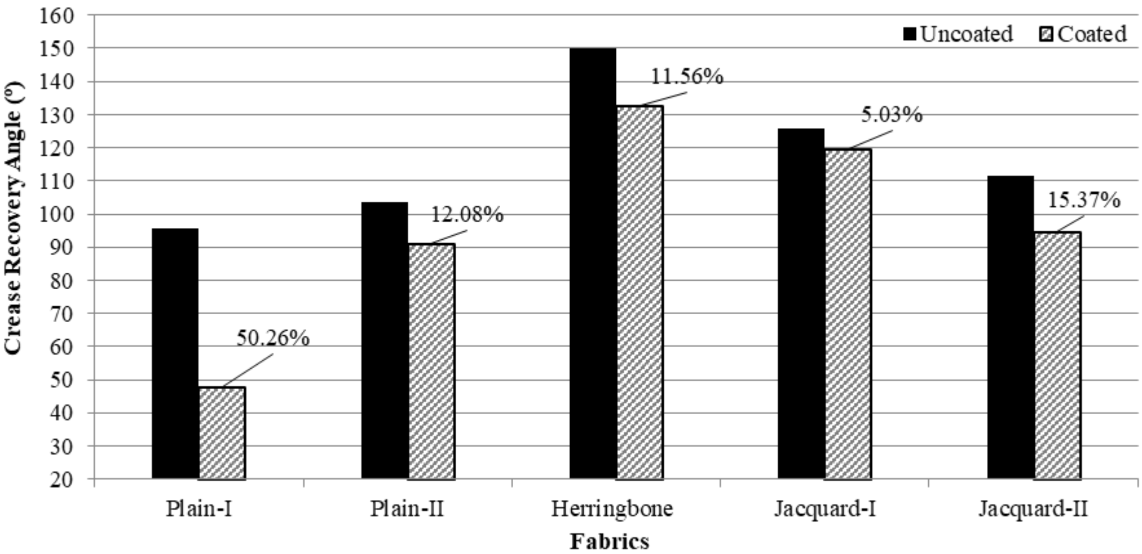


Figure 14. Crease recovery angle of fabrics

Figure 13 shows that the bending rigidity values of the fabrics after the coating process tend to Herringbone > Jacquard-II > Plain-II > Jacquard-I > Plain-I.Figure 14 shows that the crease recovery angle values of the fabrics after the coating process tend to Herringbone > Jacquard-I > Jacquard-II > Plain-II > Plain-I. When the relationships between the bending rigidity and crease recovery angle tendencies of the fabrics after the coating process were evaluated, the crease recovery angle value of the coated fabric with high bending rigidity (as in herringbone fabric) was also obtained high, in other words, the ability to recover after folding was better, while the crease recovery angle value of the coated fabric with low bending rigidity (as in plain-I) was also obtained low, in other words, it became difficult to return to the initial state after folding.

However, when Figures 13 and 14 were examined, while the bending rigidity of all fabrics increased after the coating process, the crease recovery angle values decreased. Therefore, it was thought that the results in the trends explained above (for herringbone and plain-I structures) were affected by the structural properties of the base fabric. It could be stated that the fabric with a high crease recovery angle value in the uncoated state also gave a high crease recovery angle value after the coating process, and the fabric with a low crease recovery angle value in the uncoated state also gave a low crease recovery angle value after the coating process.

The t-test results for bending rigidity and crease recovery angle of the fabrics in the uncoated and coated state are presented in Table 5. The p-values less than the significance level ($\alpha = 0.05$) in these tables indicate a significant difference in results.

Table 5. T-test results for bending rigidity and crease recovery angle of the fabrics in the uncoated and coated state

	p-values	
	Bending rigidity	Crease recovery angle
Plain-I	0.0002*	0.0007*
Plain-II	0.0034*	0.0037*
Herringbone	0.0295*	0.0026*
Jacquard-I	0.0041*	0.0019*
Jacquard-II	0.0014*	0.0198*

**significant difference*

4. CONCLUSION

This study investigated the effects of the acrylic coating process applied to woven fabrics with different structural parameters on various surface (roughness and friction coefficient) and the fabrics' physical performance (permeability and handle) properties.

Experimental results show that the acrylic coating process generally reduced the surface roughness parameters of the fabrics, which might vary depending on the base fabric texture. The surface roughness decreased as a result of the filling of the gaps between the indentations and protrusions in the surface texture of the base fabric after the coating, and also calendering process. And these reduction rates were affected by the structural parameters of the base fabric. Similarly, the friction coefficients of the fabrics decreased after the coating process, and these reduction rates were also affected by the structural parameters of the base fabric.

After the coating process, the fabrics' air permeability, water vapor permeability, and thermal resistance values decreased. The fabric structure that showed the highest decrease in air permeability values among the fabrics examined was the plain weave structure, followed by the jacquard weave fabrics, and the structure that gave the highest air permeability after coating was the herringbone fabric. It was seen that the decrease in water vapor permeability values after coating was affected by the fabric construction. The decrease in water vapor permeability values after coating was high in high mass per unit area plain fabric, despite having the same weave structure, while the decrease in water vapor permeability after coating was low in low mass per unit area plain fabric. After coating, the decrease rates in water vapor permeability values of jacquard fabrics were high, while it was less in herringbone fabric. After the coating process, the thermal resistance values of all examined fabrics decreased, and the highest decrease occurred in the herringbone structured fabric.

Bending rigidity values of fabrics increased significantly after the acrylic coating process. The crease recovery angles of the fabrics decreased after the coating; in other words, it became difficult to return to their initial state after folding. The results showed that the bending rigidity increased after the coating process, and the crease recovery angle values decreased. However, when the relationships between the bending rigidity and crease recovery values of the fabrics after coating were examined, it was seen that the crease recovery value of the fabric structure with a high bending rigidity value after coating was also high. Therefore, it was considered that this result was affected by the structural properties of the base fabric. It could be stated that the fabric with a high crease recovery angle value in the uncoated state also gave a high crease recovery angle value after the coating process.

As a result of this study, it was observed that the fabric surfaces after the acrylic coating gained smoother and lower friction coefficient properties, and by taking into account other physical performance properties such as permeability and handle properties of fabrics after coating, it could contribute to the determination of fabric structural parameters to be taken into consideration in the selection of the base fabric to be coated for the desired area of use.

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