

## Coated Textile Materials

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### 1. Introduction

Top finishes began to be used already in the 18th century when fabrics were coated with linseed oil to produce oilcloth. This was the first procedure of coating several agents to the textile substrate and can be considered as the predecessor of multi-layered materials. Textile surface materials coated with chemical structures have been developed continuously for several last 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 products with the basic textile material has many improved properties and multiple advantages over the classic textile material [1 - 3].

Polymer layers can be polyurethane, polyvinylchloride or polyacrylate layers. To improve their properties, appropriate additives are added: softeners, porosity-generating agents, filling materials, binders, fungicides etc. Coated polymers are applied to the textile material directly, and indirectly using paper or coagulation procedure. The constant development of the coating technique resulted in the newest achievements the result of which is the application of nanoporous polymers to the textile substrate. The use of these products is increasing and they are gaining greater importance in the clothing industry. They are especially widespread in the protective clothing where they meet all the market requirements. The design of a multilayered material is based on a target product so that it is very easy to obtain a material with desirable properties. As it is not always possible to satisfy the market with classic textile materials made of textile fibers and yarn, especially the requirements of the protective clothing, after-treatments of textile materials were introduced, either by applying polymers or some other agent or by thermal joining several different laminates. This was the introduction of the so-called composite materials which according to their structure and properties were in line with the requirements for specific purposes. With their especially good properties such as strength, durability, protection against UV radiation, wind, rain and other necessary properties they did not lose comfort, airiness, design and easy care. Multilayered materials, especially in the textile industry, contain at least one layer of the textile material which may be a woven fabric, knitted fabric or nonwoven fabric, whose only function is primarily comfort (comfort is the emotion of pleasant feeling related to tactile sensation, while pleasant is a broader term, a person can be pleasant), elasticity and airiness. Multilayered materials can be produced in different ways:

- by laminating a polymer layer to the textile surface material,
- by direct applying a polymer to the textile material,
- by indirect applying a polymer to the textile material.

The chemical compositions of polymer coatings are constantly developed and new types of polymer additives are increasingly introduced. The influence of industry globalization, the requirements of suppliers and consumers as well as new technologies change the market and expand the use of polymer coated textile materials.

The key factor for the success of polymer coating is its versatility and long durability. This chapter will deal with polyurethane (PU) polymer coats with different nanopores for coating and laminating the textile. Abrasion resistance and strength are by far higher in polyurethane in comparison to other polymers. Polyurethane has the property of good adhesion which can be strengthened by addition of cross-linking agents. Hardness or softness can be achieved by variation of polymer structures without using a plasticizer. It is also possible to reduce fragility by the impact of light [1, 4].

## 2. Lamination of fabrics with nanopur coating

Laminated fabric with polyurethane coating with nanopores is a multilayered composite material. Textile composite materials are composed of two or more different materials with at least one textile layer (woven fabric, knitted fabric or nonwoven material). All components composing the final product affect the properties of multilayered composites. The portion of individual components can be different which enables obtaining a composite with target properties for the predetermined purpose. Nowadays the material with woven fabric on the front side and polyurethane with nanopores on the back side is mostly used for military or police outerwear as well as for civil uses. For military purposes camouflage fabric in different shades and designs or less frequently single colored is used, while single-colored fabrics in blue shades are used for police purposes. This kind of composites have multiple advantages over the classic fabric since they are more durable and stronger, their body protection against meteorological effects (rain, wind, UV radiation), they did not lose their comfort (they are airy and have good sweat permeability), they are more resistant to abrasion and load, and they have less anisotropic properties in contrast to the classic fabrics.

Properties of composites with the woven fabric as the basis depend to a great extent on weave type, warp and weft density, yarn count and the angle of the straight line under which the load acts in relation to the warp and weft direction. The highest breaking strength is expected in the warp direction and then in the weft direction. According to the previous investigations the stress of the composite material with the woven fabric outside the warp and weft direction considerably reduces fabric breaking force. Through the action of the external force on the composite material the internal cohesion forces resist more strongly to the warp and weft direction in relation to other directions. The relaxation of the internal forces in the state of stress begins earlier if the force acts under a certain angle in relation to the warp and weft direction. This phenomenon defines fabric anisotropy which reflects on the composite material with one or more fabric layers. Load is expressed as the ratio of the internal forces acting on the area unit of the sample [5-7].

Deformations of the materials used for making clothing occur in joint areas such as elbows, knees and sitting trouser part due to multiaxial loading. After longer loading in the places mentioned deformations occur expressed as irreversible elongation and baggy appearance

of the garment at this place. Using composite materials reduces this phenomenon in relation to standard fabrics, especially by use of nanopur coating on the back side of the fabric because it increases durability and strength of the composite material, while on the other hand it decreases anisotropy.

To join the fabric with other materials a binder for better adhesion or only thermal joining is used. Figure 1 shows examples of laminating a fabric to a fabric or fabrics with other materials.

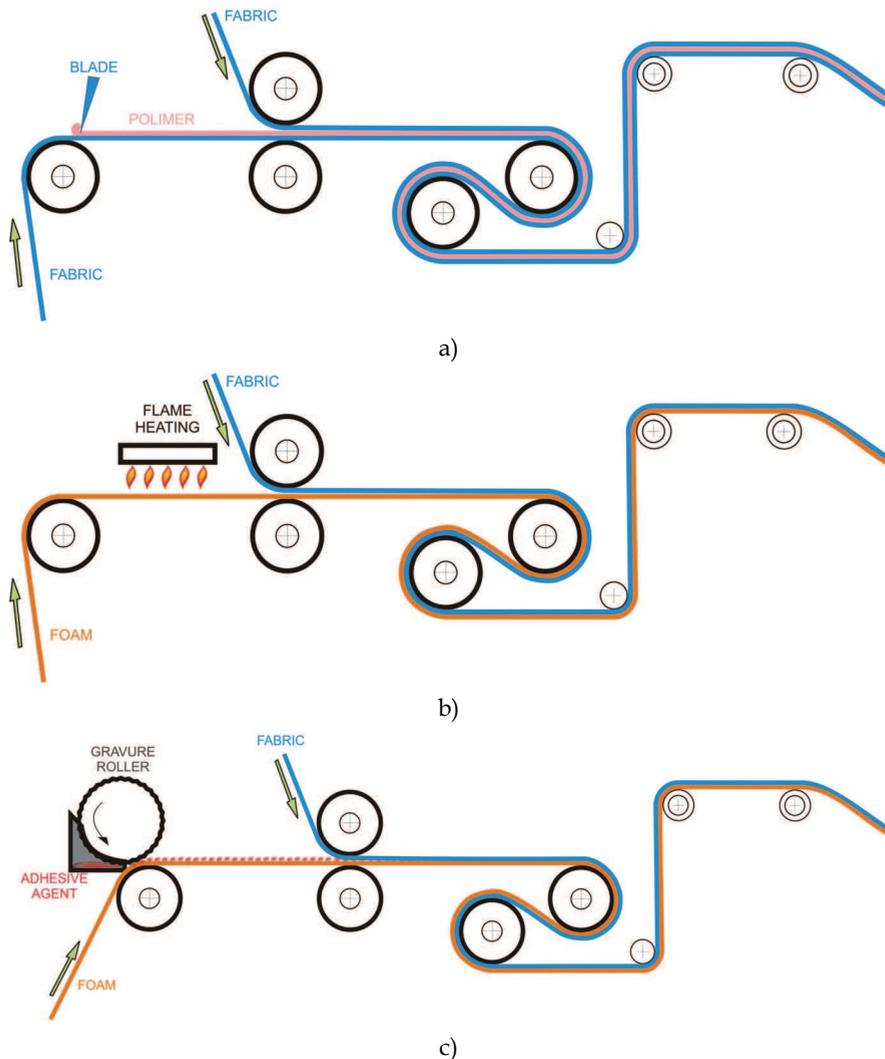


Fig. 1. Fabric lamination

a) lamination of two fabrics using a binder, b) foam lamination of the fabric using thermal joining, c) foam lamination of the fabric using a binder

### 3. Polymer coating on the textile material to produce the so-called artificial leather

Polymer coating on the textile material provides new properties of the fabric. Polymer-coated textile materials have a wide range of application, from the textile industry to technical textiles. The advantage of this kind of textiles in the clothing industry is their water impermeability, while on the other hand they are air and water vapor permeable, resulting in good properties of concurrent protection and comfort. Depending on the use, nonwoven, woven or knitted fabric is used as coating substrate. As far as their properties are concerned, new man-made fibers or materials can be similar to natural or even they can surpass the properties of natural fibers, resulting in an increasing application for coated materials. Nowadays companies are adapting to new challenges, they are trying to expand the domestic and world market; thus, it is understandable that great efforts are being made to develop new products and to improve the properties of the available ones. As the substrate for coated materials synthetic (perhaps better to say artificial than synthetic) materials are frequently used due to their relatively high strength and good abrasion resistance. Artificial materials possessing high elasticity, airiness and appropriate strength are used as the substrate for coated materials. They are mostly used for protective and sports clothing for children and adults.

It is important that the properties of the substrate meet the requirements of the final product. The following substrate parameters are of special importance:

- good mechanical properties such as elasticity, elongation at break, strength, frictional resistance,
- type of yarn: filament and texturized yarn, where spun yarn exhibits good adhesion because of protruding fibers which excellently join with the coat, but when making thin polymer materials these short hairs or cut filaments can penetrate the surface, causing water permeability of the fabric,
- dimensional stability,
- adhesion, absorption – the substrate must have good binding properties so that the coating could penetrate the substrate to a sufficient extent, and binding characteristics could improve by addition of the binding agent either in the pretreatment of the substrate or in the PU coat,
- pretreatment – agents such as softeners and dyes can negatively affect the subsequent production procedure; several treatment types, such as water repellent and antibacterial treatment can improve the properties of the final product,
- thermal stability – PU coating requires high temperatures to form the film, and thus the substrate have to endure high temperatures,
- uniformity of the substrate – uniform substrate thickness is a particularly important feature for subsequent treatments [4, 8, 9].

Polyurethane is mostly used for coating the textile material. The coating procedure can be direct or using siliconized paper. When polyurethane is coated directly, the polymer is coated using special coating blades indirectly to the textile material (Fig. 2a). When coating is indirect, the polyurethane polymer is coated first to the paper, and then is laminated with the substrate and the textile material respectively (Fig. 2b). When it is first coated to the paper, it can be in several layers. After each coating, the polymer is dried and cooled down. Upon completion of the coating procedure, the paper is separated from the finished material. The paper returns to the machine entry and can be used for further coatings, approximately from 8 to 10 times. This method is applied for low density fabrics so that the

coated polyurethane remains on the back of the textile material and cannot penetrate to the front side. By adhesion to the fabric and by partial penetration into the fabric structure the PU coat remains permanently bonded and fused into a compact material. The composition of the layers in case of indirect PU coating does not need to be always the same, neither in the composition nor in the coating thickness. Both the material composition and the coating thickness and the number of coating procedures depend on the application of the final product.

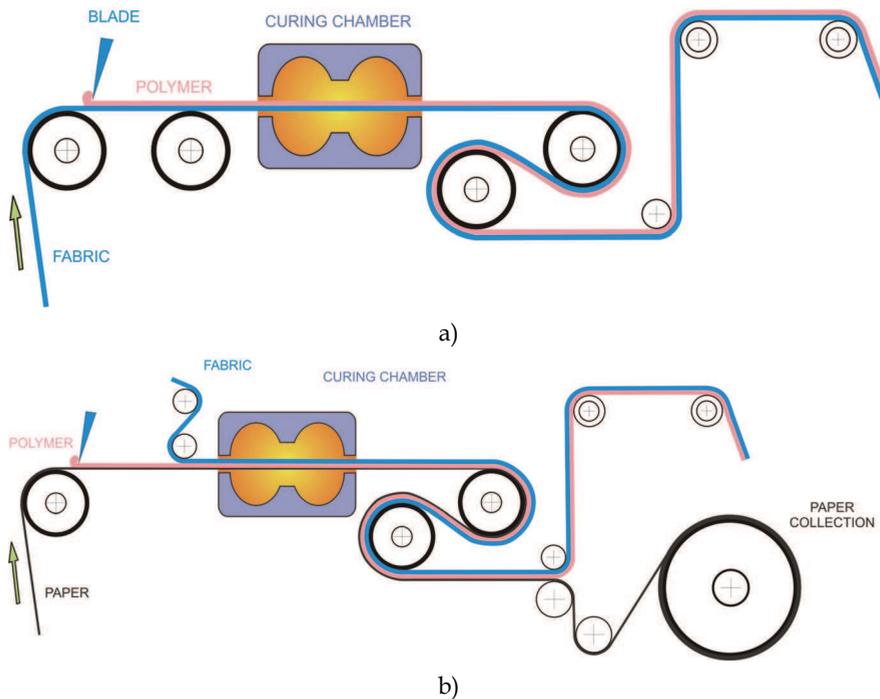


Fig. 2. Schematic of the process of polyurethane coating  
 a) Direct coating with one passage, b) Indirect coating using silicone paper with one coating passage

### 3.1 Polyurethane (PU) coating

The selection of polymers is very important to obtain desirable properties of the finished product, and the coating composition is determined according to the application of the finished product.

The coating consists of the basic polymer and additives. In the selection of the basic polymer the properties are as follows: thermo plasticity, mechanical properties of polymers, possibility of film formation, stiffness, good adhesion, abrasion resistance, heat, water and air conductivity, resistance to solvents and hydrolysis, resistance to UV radiation, melting point etc.

The basic polymer is mostly polyurethane that may be strong and rigid, soft and elastic. Polyurethanes belong to the group of very durable plastic materials. The main property of

polyurethane is its wide application. It can be coated to textiles, leather, in solution, dispersion, with a low solvent content or without it, as granules or powder. Softness or hardness can be obtained by varying polymer structures.

Polyurethane has good washproofness and cleaning resistance, good adhesion to the fabric, good durability at low temperatures, it is possible to use it without softeners, it has good viscosity and abrasion resistance, at the same time it has a pleasant and soft touch, a low specific mass, resistance to oils and fats. Polyurethane can be coated to textile materials in more ways:

- as a two-component polyurethane with isocyanate cross-linking,
- as one-component aromatic or aliphatic polyurethanes with chemical reactions performed in the production, and during the coating and drying process it is linked between evaporation chains and solvents,
- as a one-component product that enables dispersion in water and is environmentally friendly
- as a solid product with possible coating of greater quantities in each coating passage.

### 3.2 Additives

Additives improve properties of coating polymers such as:

- softeners imparting better flexibility and softness of the finished multilayered product, and they enable a more uniform distribution of the polyurethane paste (Vithane),
- cross-linking agents and binders that improve the bond between the textile material and the coated polymer (Larithane CL 1, Larithane MA 80, Toulén),
- antimicrobial agents (Sanitized),
- light fastness agents (Tinuvin),
- various pigments for dyeing the polymer coating (pigments).

To achieve a good material quality, it is very important to dose the solvent regularly in the binding coating. Too small a quantity of the solvent in the binding coating causes the swelling of the binder instead of its dissolving, resulting in poor bonding of the material to the substrate. On the other hand, too great a quantity of the solvent in the binding coating causes too rapid dissolving of the binder, resulting in too great penetration of the PU coating into the substrate. The final result is too great material rigidity [5].

## 4. Properties of coated textile materials

Properties of coated textile materials primarily depend on their application. Nowadays modern technologies, optimization of the conditions of the production process and use of certain agents and recipes enable making a target product which will meet all the requirements. Since it is not possible to use the classic textile for many technical purposes, excellent properties are obtained by combination with other substances which are coated in the form of paste or laminated to the material. By use of the value-added material, nanoproductions and modern technology the use of textile materials has been enhanced several times. For the purposes of this study samples of the woven fabric with nanopur coating on the back side were chosen to test basic properties. They are used for police and military uniforms. The fabrics have the same construction parameters in different colors and different properties of the nanopur coating (Tables 1 and 2).

Likewise, samples of the artificial leather with polyurethane coating on the knitted fabric, namely with different properties of polyurethane in two colors (Table 3), will be considered.

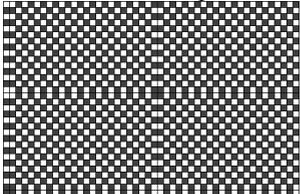
Woven fabric parameters	Yarn/woven fabric			Laminated fabric		
	Green	Blue	Camouflage (printed)	Green	Blue	Camouflage (printed)
Fabric weave	Plain weave + Rep weave 					
Thread density/10 cm warp / weft	360 / 207					
Count of warp/weft (tex)	17x2 / 40					
Raw material composition of warp/weft	(PA 6.6/ cotton 50/50) / (PA 6.6/ cotton 50/50)					
Warp yarn twist single/plied/weft (turns/m)	938/622/673					
Fabric thickness + nanopur coating (mm)	0.39	0.39	0.39	0.41	0.41	0.41
Mass (g/m <sup>2</sup> )	217	220	211	266	271	259

Table 1. Basic parameters of fabrics and yarns in fabrics

Laminate	Color	Nanopur coating	Properties of laminated fabric
1	Green	Nanopur FR 30 - 30 g/m <sup>2</sup>	Not made water-repellent
2	Dark blue		Made water-repellent
3	Camouflage		Made water-repellent

Table 2. Properties of the laminated fabrics and polyurethane nanopur coating

#### 4.1 Anisotropy of multilayered materials

Coated textile products either as artificial leather or as laminates assume properties of the materials they are made of. Since they are partially made of the textile that is in its properties mostly anisotropic, coated material as a whole is also anisotropic, meaning that the coated material behaves differently in different direction when stressed.

Two features are differentiated related to material load, namely: determination of the dependence of strength on the direction of force application in relation to the directions of the body structure known as anisotropy and assessment of the strength of anisotropic bodies in the case of complex states of stress [10-14].

Anisotropy of woven and knitted fabric is outstanding. Anisotropy is reduced by addition of a coating agent, but it is not eliminated. Thus, the properties of coated materials do not only depend on the components, but also on the direction of load.

In woven fabrics laminated with nanopur coating outstanding anisotropy is observable in all three samples (Figs. 3 and 4). The differences in the samples are in fabric color and hydrophobicity (Table 2). An exceptionally high anisotropy is present in the fabrics without nanopur coating. The highest anisotropy of breaking forces is visible in the camouflage

fabric, and the lowest one in the single-colored, blue fabric. The highest sensitivity of all the fabrics is when they are loaded at an angle of 15°, then at an angle of 75° followed at angles of 30° and 60°. The essential point is that the fabric at an angle of 45° is even more strongly than in the weft direction. This means that the threads in the binding points are strongly bound and they do not allow shearing at an angle of 45°. Since the fabrics were woven in the combination of plain and rep weave with a relatively high density in the warp and weft direction, their compactness is outstandingly high. The thermal joining of the nanopur foil

Sample	Color	Mass (g/m <sup>2</sup> )	Thickness (mm)	1st coating	2nd coating	3rd coating	Knitted fabric	Property of artificial leather
I	White	185	0.58	Larithane AB 4228	Larithane AB 4228	Ucecoat ID 9229	Plain jersey, mass: 90 g/m <sup>2</sup> , raw material composition 100% PA 6.6, thickness: 0.45 mm	Standard recipe
Ia	Blue	175	0,56	Larithane AB 4228	Larithane AB 4228	Ucecoat ID 9229		Additional flameproof treatment in the 1st and 2nd coating
II	White	188	0.55	Larithane AB 4228 + Lomaflam TDCP	Larithane AB 4228 + Lomaflam TDCP	Ucecoat ID 9229		
III	White	187	0.50	Larithane AB 4228	Larithane AB 4228	Larithane BTH 146 + Larithane CL 16	In the 3rd coating polyurethane was used, it has greater water vapor permeability	
IIIa	Blue	163	0.48	Larithane AB 4228	Larithane AB 4228	Larithane BTH 146 + Larithane CL 16		

Table 3. Basic parameters of polyurethane coating, knitted fabric and artificial leather

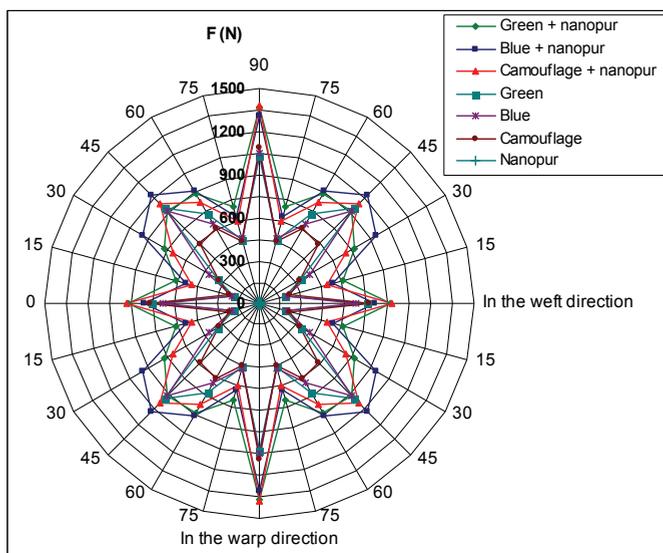


Fig. 3. Breaking force in different directions

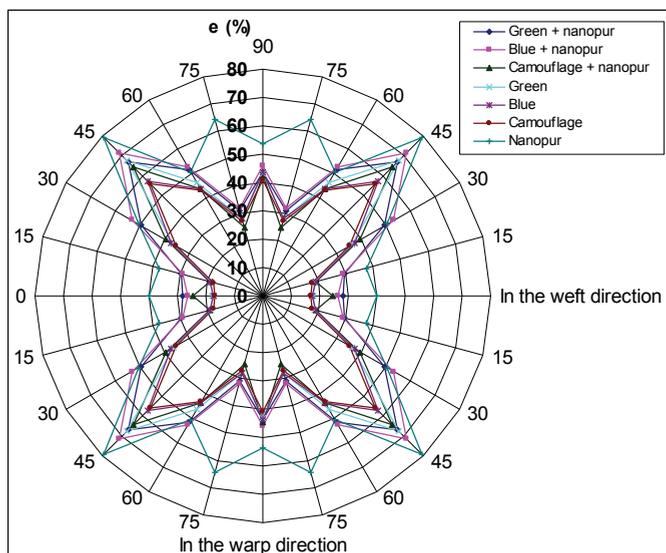


Fig. 4. Elongation at break in different directions of the fabric samples with nanopur coating to the back side of the fabric increased material strength and reduced fabric anisotropy. However, anisotropy is present and follows the course of fabric anisotropy. The nanopur foil does not have outstanding strength and is almost invisible in the polar diagram. The breaking forces of the samples containing the fabric mostly followed the course of breaking forces, except in the weft direction where elongation at break is the lowest. The nanopur foil has an outstandingly high elongation at break which is in most cases higher than in the samples containing the fabric and its anisotropy is lower. The highest elongation at break occurs in all samples at an angle of 45°, and the lowest in the weft direction.

In the case of artificial leather the material strength is changed by altering the composition of coating (Fig. 5). Anisotropy of all materials in all testing directions is noticeable. Nevertheless, the course of the curve of breaking forces is almost identical in all three samples, and there is no difference among the samples. The greatest sensitivity of all materials is at angles of 15° and 30°. The highest breaking forces are in the warp direction or in the sample length, then at angles of 75° and 60°. In the weft direction or in the sample width breaking forces are similar as in the direction of 45°. The knitted fabric has a little lower breaking force than the artificial leather in all testing directions, meaning that the breaking force did not increase substantially by coating the polyurethane layer to the knitted fabric. Elongation at break is also different according to testing levels, and there is no particular difference among the samples (Fig. 6). The highest elongation at break is observable in the weft direction in all samples, and it is the lowest at angles of 60° and 75° and in the warp direction. The anisotropy of the artificial leather assumed the anisotropy of the knitted fabric, when observing breaking forces and elongation at break. The samples of artificial leather and knitted fabric for testing breaking force and elongation at break were prepared in dimensions 200x50 mm and tested on the Statimat M tensile tester made by Company Textechno in accordance with the standards ISO 13934-1:1999; EN ISO 13934-1:1999.

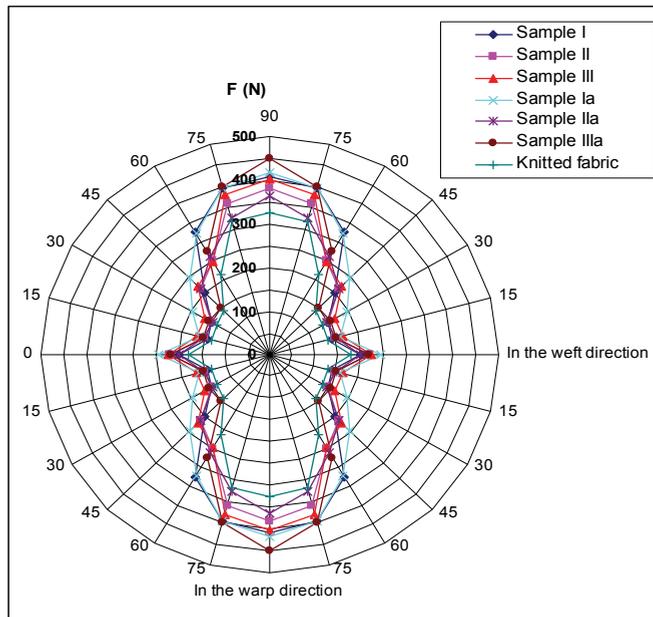


Fig. 5. Breaking force in different directions of the artificial leather (polyurethane coating + knitted fabric) and the knitted fabric before PU coating sample I, II, III - white samples defined according to Table 3; Ia, IIa, IIIa - blue samples defined according to Table 3

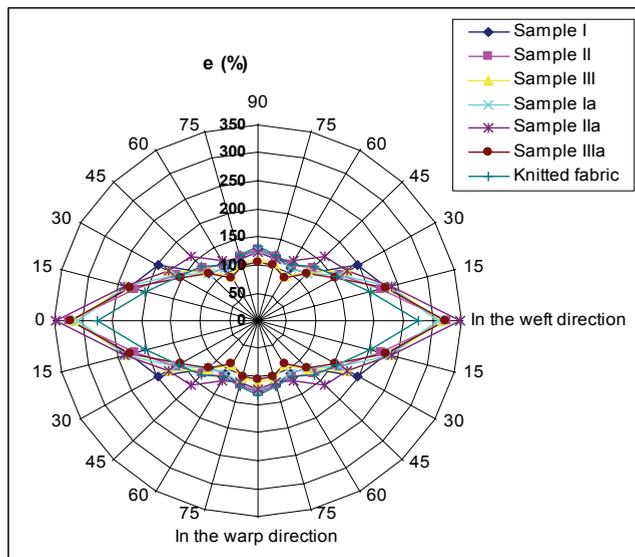


Fig. 6. Elongation at break in different directions of the artificial leather (polyurethane coating + knitted fabric) and the knitted fabric before PU coating sample I, II, III - white samples defined according to Table 3; Ia, IIa, IIIa - blue samples defined according to Table 3

### 4.2 Abrasion resistance

To test the abrasion resistance of laminated fabrics with nanopur coating, the determination of mass loss by the Martindale method after 5,000 and 10,000 cycles according to the standard ISO 12947-3:1998+Cor 1:2002; EN ISO 12947-3:1998+AC 2006 was used. According to the results obtained, a certain difference between the samples of the laminated fabrics and the artificial leather is noticeable. The lowest loss of mass records the blue sample followed by the green sample, while the printed or camouflage sample records the highest difference (Fig. 7). In the artificial leather with knitted fabric on the back the loss of mass is also different (Fig. 8). The first white sample records a slightly lower loss of mass than the blue sample, while the other two samples in blue color record a noticeably higher loss of mass. This means that the pigments applied in the artificial leather affect the coating in such a way that they reduce abrasion resistance. The white coating has a lower loss of mass than the coating dyed with blue pigments.

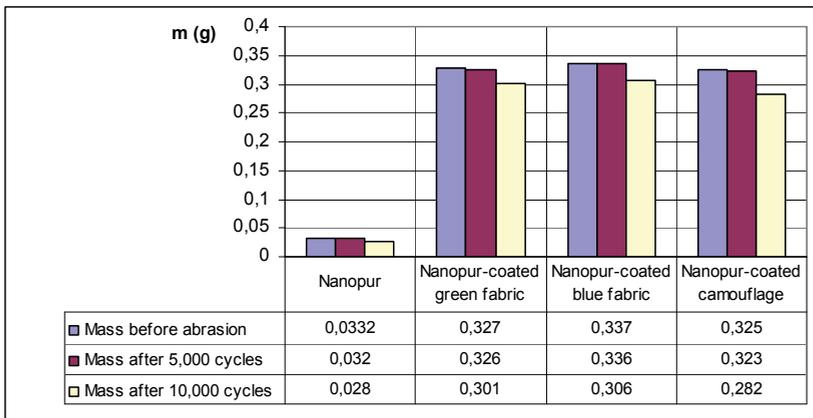


Fig. 7. Mass loss of the nanopur-coated laminated fabrics

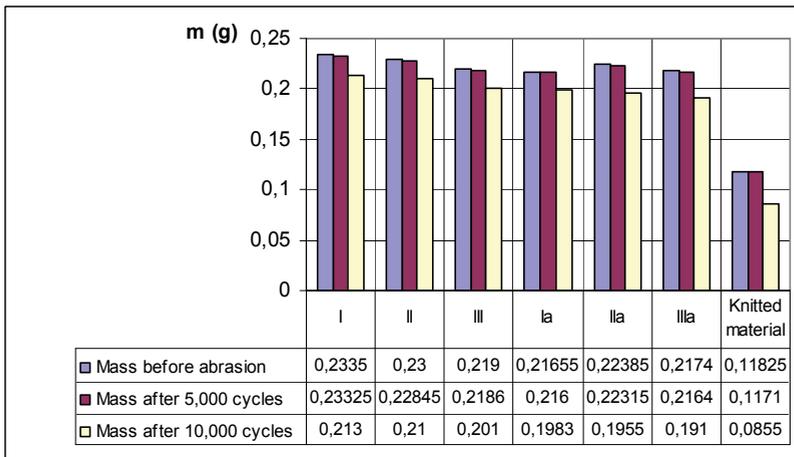


Fig. 8. Mass loss of the coated textile materials

### 4.3 Bursting strength

The determination of bursting strength with a steel ball was carried out in accordance with the standard AN 12332 1:1998, ASTM 3787 using a strength tester made by Aparecchi Branca S.A., Italy. On the basis of the results obtained there is a difference in bursting strength and elongation at break among the tested fabric samples. The nanopur-coated blue fabric has the highest bursting strength, while the camouflage fabric has the lowest values (Fig. 9). The nanopur-coated blue fabric having the highest bursting strength has the lowest anisotropy (Fig. 10).

Differences in bursting strengths are also visible in the artificial leather (Fig. 10). Samples III and IIIa have the highest bursting strength, while samples I and Ia have the lowest values. It is essential to emphasize that white samples (I, II and III) have higher bursting strength and elongation at break than the blue ones (Ia, IIa, IIIa), which is not the case in testing bursting strength using strip test method (Fig. 5).

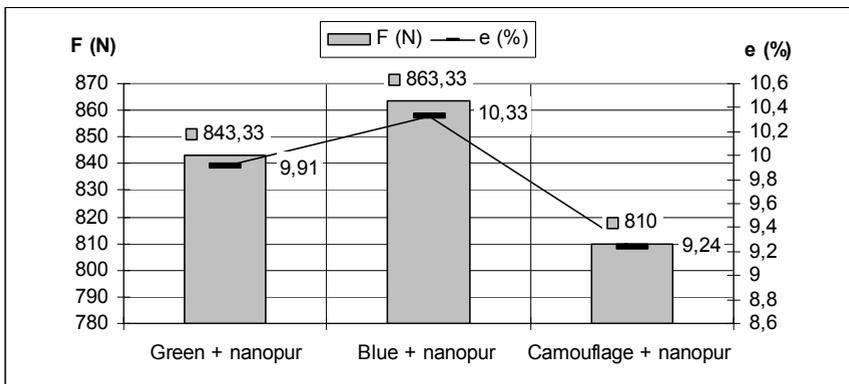


Fig. 9. Bursting strength of the artificial leather

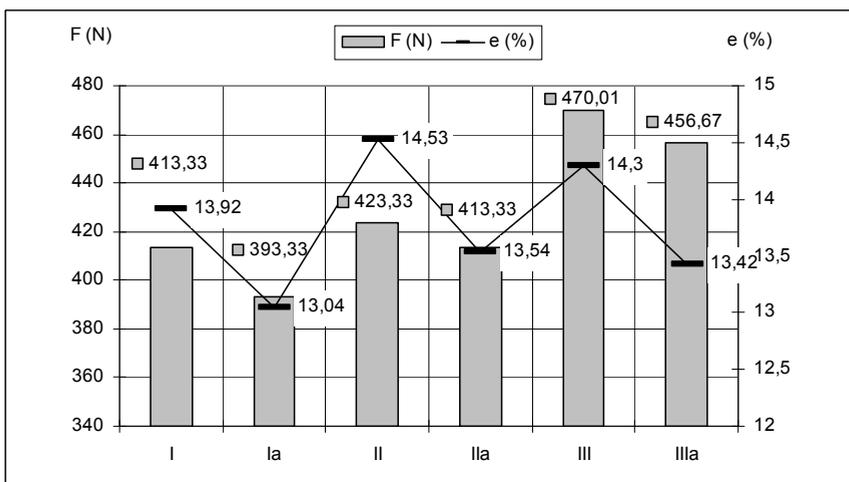


Fig. 10. Bursting strength of the nanopur-coated laminated fabrics

#### 4.4 Thermal resistance

The determination of thermal resistance was performed in accordance to the standard ISO 11092 on the Sweating Guarded Hotplate made by MTNW, USA. According to the results obtained for the laminated fabric samples there is a certain difference (Tab. 4). The white fabric exhibited the highest thermal resistance before and after lamination, while the camouflage fabric exhibited the lowest thermal resistance. In the case of the artificial leather there is also a certain difference in thermal resistance among the samples. Flameproof samples (III white and IIIa blue) have the highest thermal resistance, while the samples with higher water-vapor resistance have the lowest thermal resistance.

No.	Sample designation	Measured value $R_{ct}$ ( $R_{ct} - m^2KW^{-1}$ )	
		$\bar{X}$	CV (%)
1	Knitted fabric	0,0053	6,71
2	Green	0,0111	5,43
3	Blue	0,0127	7,36
4	Camouflage	0,0115	6,88
5	Green + nanopur	0,0101	4,31
6	Blue + nanopur	0,0113	4,06
7	Camouflage + nanopur	0,0103	5,62
8	Nanopur	0,0091	3,55
9	I	0,0134	4,71
10	Ia	0,0200	3,20
11	II	0,0143	3,70
12	IIa	0,0220	3,75
13	III	0,0105	4,88
14	IIIa	0,0113	3,80

Table 4. Thermal resistance using the sweating guarded hotplate

#### 5. Conclusion

On the basis of the performed theoretical considerations, design of the coated textile products and corresponding properties, it is possible to make a target product which will meet all requirements. In the case of the observed multi-layered textile composites, it is necessary to define material anisotropy in the weakest directions, which are also the most responsible for deformation. In these places deformations in form of changes in material dimensions per unit of length are created and the so-called baggy shape results.

By use of woven fabrics as the basic layer of textile structured multi-layered composites in laminating a relatively high anisotropy occurs which can be reduced by polymer coating. However, due to an exceptionally good strength in the warp and weft direction and its abrasion resistance, breaking and good physiological properties its presence will be relatively widespread in relation to knitted and nonwoven fabrics. The use of the fabric on the composite front side provides great design possibilities such as printed fabric for camouflage military clothing etc.

By coating polyurethane paste to textile materials, materials known as artificial leather is obtained. They occupy an important place on the market. Artificial leather is unthinkable without the textile substrate. In most cases these are woven or knitted fabrics which transfer their properties to the final properties of artificial leather. Since they are materials mostly used as outerwear or upholstery fabrics, their physiological properties are essential. Air,

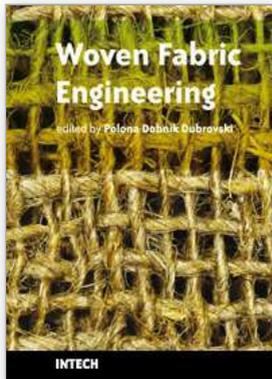
water and water vapor permeability, their strength and durability depend on the properties of individual properties of coated materials and final products. Since structured multilayered materials consist of different materials and various binders, besides material comfort it is important to pay great attention to their compatibility in different conditions. The target product to meet market requirements can be produced by appropriate selection of recipes for polymer coating, and by determination of construction parameters of the textile fabric as well as raw materials and production conditions.

Subsequent investigations should include multiaxial testing of a series of models with different woven and knitted fabrics in order to reduce anisotropy, especially of the materials being less strong and having higher elongation. A change in polymer coatings and their properties related to textile materials affect final properties of multilayered materials. Likewise, adding a target polyurethane coating and after treatment, even the selection of color can provide a target product with appropriate properties.

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The main goal in preparing this book was to publish contemporary concepts, new discoveries and innovative ideas in the field of woven fabric engineering, predominantly for the technical applications, as well as in the field of production engineering and to stress some problems connected with the use of woven fabrics in composites. The advantage of the book *Woven Fabric Engineering* is its open access fully searchable by anyone anywhere, and in this way it provides the forum for dissemination and exchange of the latest scientific information on theoretical as well as applied areas of knowledge in the field of woven fabric engineering. It is strongly recommended for all those who are connected with woven fabrics, for industrial engineers, researchers and graduate students.

### **How to reference**

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