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Influence of Warp Density on Physical-Mechanical Properties of Coated Fabric

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Abstract

This paper examines the influence of different warp densities on changes of relevant physical-mechanical properties of coated fabrics. Coating process of cotton fabric was performed by polyurethane coating.In order to examine the impact of polyurethane coating on the properties of multi-component materials, with a fabric as a basic component,tests were carried out on the fabricwith different warp densities: 24, 22, 20, 18 and 16 threads/cm before polyurethane coating. Weft density did not change and for all samples remained the same (11 threads/cm).

The results of the study indicate that physical-mechanical properties of fabric, with different warp densities, before coating, differ fromphysical-mechanical properties of coated fabric with respectivelydifferent warp densities. Just minimal warp density reduction leads to significant change of the basic fabric properties, as well as the properties of multi-component material with appurtenant fabric. Changes in warp density provide significant correlation coefficients between the warp density and physical-mechanical properties of fabrics and multi-component materials.

This research proved existence of significant influence of fabric parameters on the properties and qualitative characteristics of an end product.

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*Keywords:*multicomponent materials; coated fabric; polyurethane coating; fabric density; physical-mechanical properties

1. Introduction

In this paper, the research has been carried out on the basic physical-mechanical properties of multi-component materials. Nowadays, there is fast-growing demand for multi-component materials, which is the product of diversity of the applications of these materials, extending from the simple and everyday materials such as materials for upholstery, synthetic leather for garments, etc., to very complex materials.

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The subject of research in this paper has been a multi-component material (PU leather imitation) intended for the upholstery. It consists of the basic component – the fabric and the secondary component – PU coating.

Features of the basic component, i.e. substrate (in our case, cloth), are of exceptional importance and should meet the requirements of the end product. Following parameters are particularly important: types and characteristics of the yarn (textured yarn shows good adhesion because of the hairs which stick out and bind excellently with coating), mechanical properties of fabrics, dimensional stability, adhesion, absorption, pre-treatment, thermal stability and uniformity of substrate.

The choice of polymers is extremely important for the success of the finished material, and the coating composition is determined by the intended use of the end product. Coating consists of basic polymer (polyurethane) and additives, the quantities and types of which, together with polymerization, functional additives, method of coating and UV resistance, are of the utmost importance for the final PU coating [1,2].

Polyurethane (PU) is a polymer obtained by polyaddition reaction of isocyanates and alcohol (Fig. 1). Its characteristic is urethane group (-NH-CO-O-). Polyurethane covers a wide spectrum of application. Versality is its main characteristic (coating of textile and leather, in solution, in dispersion, with low solvent content or without solvent, as granulate or powder). Softness or hardness can be obtained by variation of polymer structures [3].

$$\underset{\text{diisocyanate}}{O=C=N-R1-N=C=O} \quad + \quad \underset{\text{diol}}{HO-R2-OH} \quad \rightarrow \quad \underset{\text{polyurethane}}{O=C=N-R1-\underset{H}{\underset{|}{N}}-\overset{O}{\overset{\|}{C}}-O-R2-OH}$$

Fig. 1. Polyuerethane synthesis [2].

Given the existence of polyester and polyether polyol, two types of polyurethane can be obtained – polyether and polyester. Polyol provides polyurethane resistance to heat, hydrolysis resistance, and possibility of swelling in solvents. Diisocyanates affect polyurethane hardness, elastic modulus, breaking force, thermoplastic and resistance to light. In this work, we usedaromatic polyester type of polyurethane, characterized by high solvent resistance, good elasticity, low hydrolysisresistance, and good abrasion resistance. Selection of the process of making leather imitation depends on the product we aim to, coating characteristics and economic factors [4-6].

2. Materials and methods

This research was carried out on samples of multi-component material (flat product consisting of several components – layers) produced in the factory Čateks Inc. Čakovec.

The basic component of tested samples makes fabric made from single cotton warp and weft yarns. After the process of desizing, the fabric was additionally napped in the finishing process. Napping is a mechanical finishing process of fabrics,implemented to achieve hairy (napped) surface, in order to obtain better bonding of PU coating.

Secondary component is represented by PU coating whose base is aromatic polyester type of polyurethane. In order to obtain multi-component material used for this research, indirect transfer coating process was applied, the concept of which consists of applying the PU coating on paper, lamination of the surface on the paper coating, drying, cooling and finally separating the paper from the finished material.

Along with multi-component material, in order to compare physical-mechanical properties, the samples of uncoated fabric were used. The observed warp density of uncoated and multicomponent sample wererespectively24 threads/cm, 22 threads/cm, 20 threads/cm, 18 threads/cm and 16 threads/cm, while weft density for all the samples was the same, that is 11 threads/cm.

Given the purpose of tested fabrics, researches that have been conducted are relevant to meet the demands placed on furniture upholstery.

Breaking properties (breaking force, breaking elongation, work to rupture and tensile strength) of the yarn were tested according to ISO 2062 on a Textechno Statimat M tensile tester.

The fabric density or number of threads per length unit was determined according to EN 1049-2:1993.

The breaking force and breaking elongation of the fabrics was tested on a Textechno Statimat M tensile tester according to ISO 13934-1:1999.

Resistance to the ball burst procedure was tested according to the HRN F.S2.022 standard on the tensile tester of the company Apparecchi Branca S.A.

The air permeability was tested according to the EN ISO 9237 standard on the air permeability air tester of the company SDL Atlas.

Also, one of the most important indicators of textile material quality and the value of the finished product is its use durability. To test the abrasion resistance of the fabrics, the Martindale method was used in accordance to ISO 12947-3:1998 – Determination of mass loss was used. Testing was done according to predetermined intervals to determine the mass loss (10.000, 25.000, 50.000, 75.000, 100.000 abrasion cycles). Mass losses were calculated for all samples according to the five intervals.

3. Results and discussion

Table 1 displays the basic parameter values of yarns, from which the fabrics of different thread densities were woven and used in this research.

Table 1. Yarns properties.

	Raw material	Tt (tex)	F (cN)	ε (%)	W (Nxcm)	ϭ (cN/tex)
Warp	cotton	40	706.53	7.84	15.42	17.66
Weft	cotton	95	1327.73	10.04	35.79	13.92

Tt - linear density (tex), F - breaking force (cN), ε - elongation at break (%), W - work to rupture (cN×tex), ϭ - breaking strength (cN/tex)

Testing tensile properties of basic and coated fabrics indicated that increasing warp density results in increasing breaking force (Fig. 2). The average increase of force, with respect to increase of warp density of every 2 threads/cm is 9.6% for basic fabrics, while for coated fabrics this increase is smaller and it is 6.5%. The influence of PU coating on coated fabric properties reflects in the increase of breaking force of coated fabrics in respect to base fabrics on average of 13.8%. Statistical analysis shows that correlation between fabric densities and breaking force indicates strong link between given parameters.

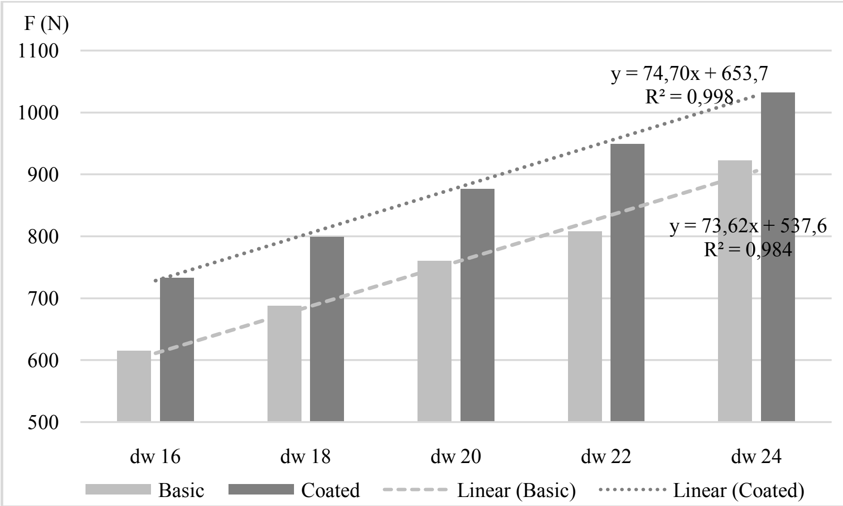


Fig.2. Breaking force (F (N)) of tested fabrics – basic and coated fabrics, where: dw – warp density (threads/cm).

By increasing the warp density for every 2 threads/cm, elongation at break of tested fabrics increases at approximately the same rate for both types of tested samples, for basic fabric on average by 3.5% and for coated fabrics by 3.2% (Fig. 3). It is also evident that with the increase of density, the increase of elongation at break decreases – by increasing density from 16 to 18 threads/cm, recorded increase in elongation at break is 5%, increasing density from 18 to 20 threads/cm is 4.9%, i.e. 4.2% (for coated fabrics); with the increase of density from 20 to 22 threads/cm, increase in elongation at break is 3.2%, i.e. 3.1% (for coated fabrics), and with the increase of density from 22 to 24 threads/cm, it is 0.9%, i.e. 0.4% (for coated fabrics). Statistical analysis showed a strong link between the correlated parameters of elongation at break and density of fabrics.

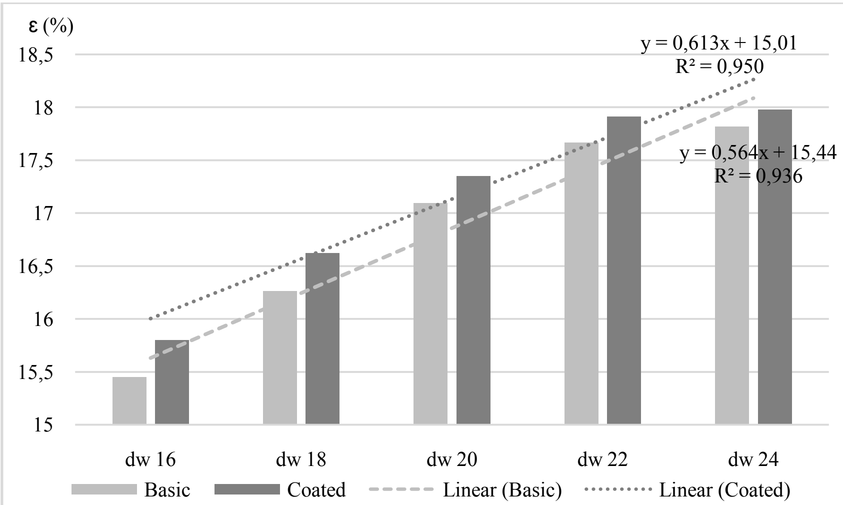


Fig.3. Elongation at break (ε (%)) of tested fabrics - basic and coated fabrics, where: dw – warp density (threads/cm).

Testing bursting strength of the fabrics provided results, which follow the trend of increasing force with increasing density of the fabric (for every 2 threads/cm) (Fig. 4). The increase is higher with the basic fabrics and is on average 5.7%, compared to coated fabrics, where this increase is somewhat smaller and is 2.9%. PU coating of the basic fabrics of all density bases, increases bursting strength by an average of 30.6%.

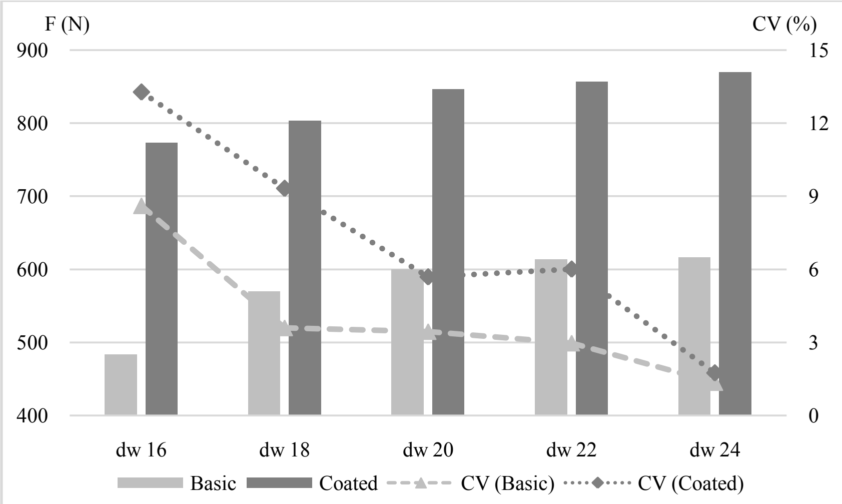


Fig.4. Bursting strength (F (N)) of tested fabrics - basic and coated fabrics, where: dw – warp density (threads/cm).

Elongation at breakduring ball bursting of fabrics increases with the increase in density (for every 2 thread/cm) of both types of tested samples (Fig. 5). This increase is also higher for basic fabrics without PU coating, and is on average 7.6%, while the increase for coated fabrics of all densities is somewhat smaller, on average 5.8%. When applying PU fabric coating, elongation at break significantly increases, on average by 24.8%.

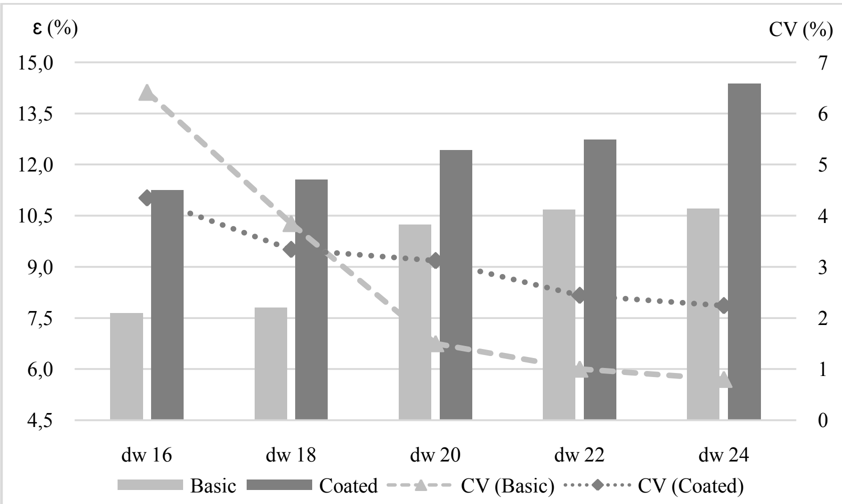


Fig.5. Elongation at break (ε (%)) during the ball bursting test of fabrics - basic and coated fabrics, where: dw – warp density (threads/cm).

Fabric air permeability (Fig. 6) decreases, as a result of the increase in warp density, for each reduction in density of 2 threads/cm, on average by 8.5% for basic fabrics, and only 2.2% for coated fabrics. Total decrease of air permeabilityfor basics fabric with warp density from 16 threads/cm to 24 threads/cm, is 30.2%, and for coated fabric it is only 8.6%. Large differences in air permeability, as expected, have been noted between basic and coated fabrics, on average 85%, which is an important indicator of the influence of PU coating on the permeability properties.

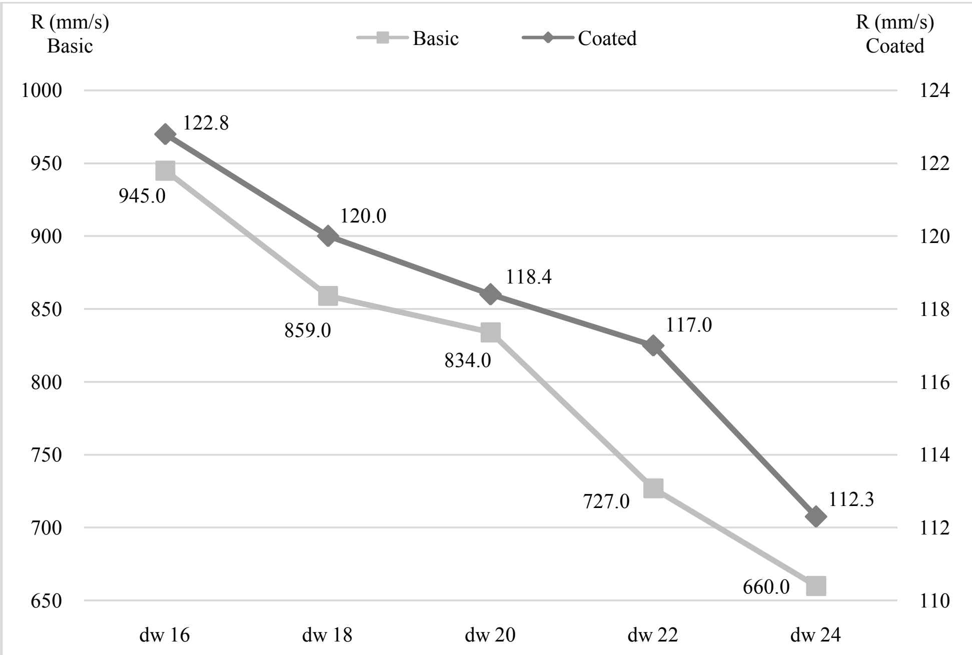


Fig.6. Fabric air permeability (R (mm/s)) - basic and coated fabrics, where: dw – warp density (threads/cm).

Abrasion resistance is a parameter which must be met in order to meet the requirements for materials used for furniture upholstery, and it describes the durability of material during use. Examining, in general, the basic fabric samples (Fig. 7), weight loss increases with the increase of warp density, and that increase is equal in proportions for all intervals. At interval 5, or 100.000 cycles of abrasive wear respectively, abrasion and a small hole on surface occurred, which is shown in Figure 9b. Within groups of different warp densities, the mass loss between each interval is the greatest between intervals 1 and 2 (10.000 and 25.000 cycles) and is on average 65%, and it linearly decreases in the following intervals: 54% between intervals 2 and 3 (25.000 and 50.000 cycles), 34% between intervals 3 and 4 (50.000 and 75.000 cycles) and 26% between intervals 4 and 5 (75.000 and 100.000 cycles).

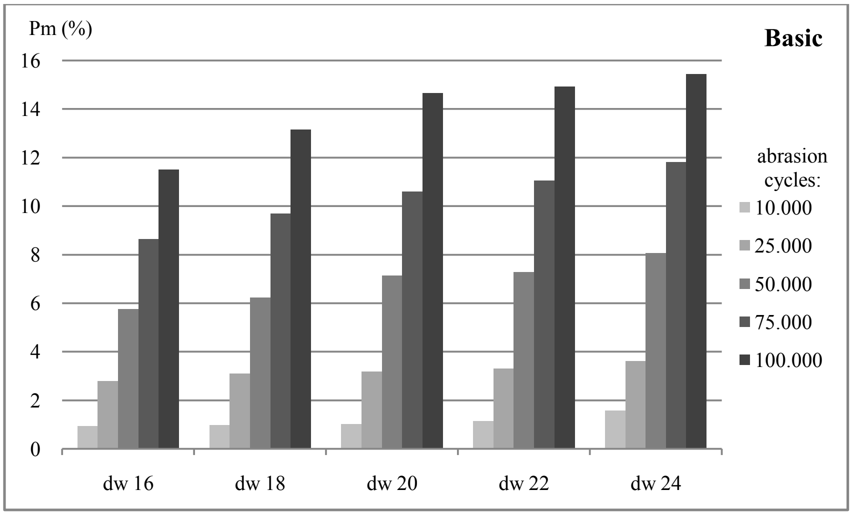


Fig.7. Abrasion resistance (Pm (%)) of tested basic fabrics, where: dw – warp density (threads/cm).

In order to be able to carry out comparative analysis of the results of abrasion resistance test of basic and PU coated fabrics, samples of the coated fabric have also been subjected to the tests under the same conditions (Fig. 8). As expected,during abrasion resistance test at five intervals, that is 100.000 abrasion cycles, samples weren't outworn, i.e., there was no appearance of deformation or damage (Fig.10d). The results of abrasion resistance, i.e. results of mass loss are displayed in Fig. 8, and in general do not indicate mass loss of samples, but mass increase. The reason for this is the transfer of flue from wearing agent (wool fabric), during the process of abrasion, on tested samples, which can be clearly seen on the back side of the material (Fig. 10g).

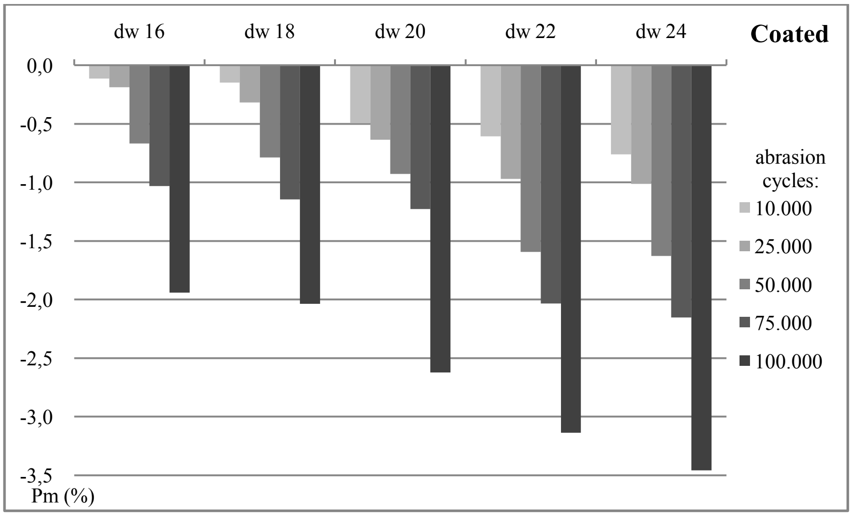


Fig.8. Abrasion resistance (Pm (%)) of tested coated fabrics, where: dw – warp density (threads/cm).

Further abrasion was conducted on samples in order to study maximum abrasion resistance. Given example relates to the sample of density 18 threads/cm. Abrasion occurred, that is, holes appeared only after 400.000 cycles. But, not even during that period did sample mass loss occur, in fact, there was mass increase for the above mentioned reasons (Fig. 9).

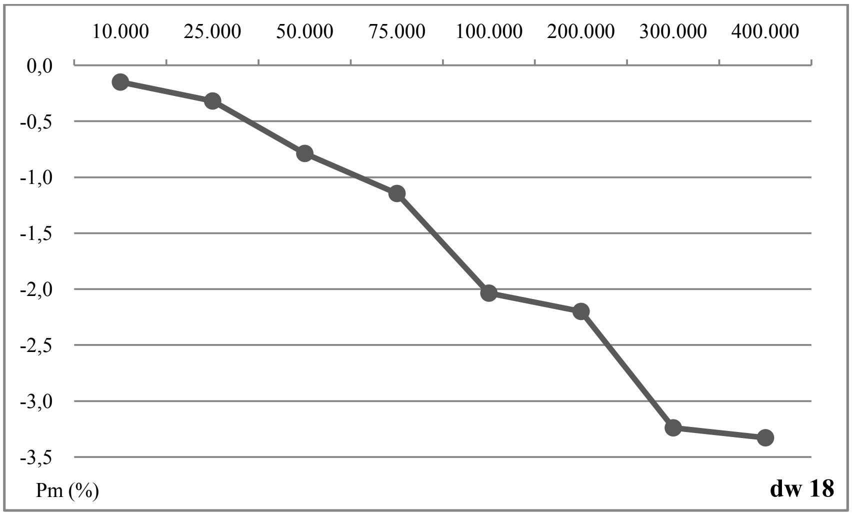


Fig.9. Abrasion resistance of coated fabric with warp density 18 threads/cm.

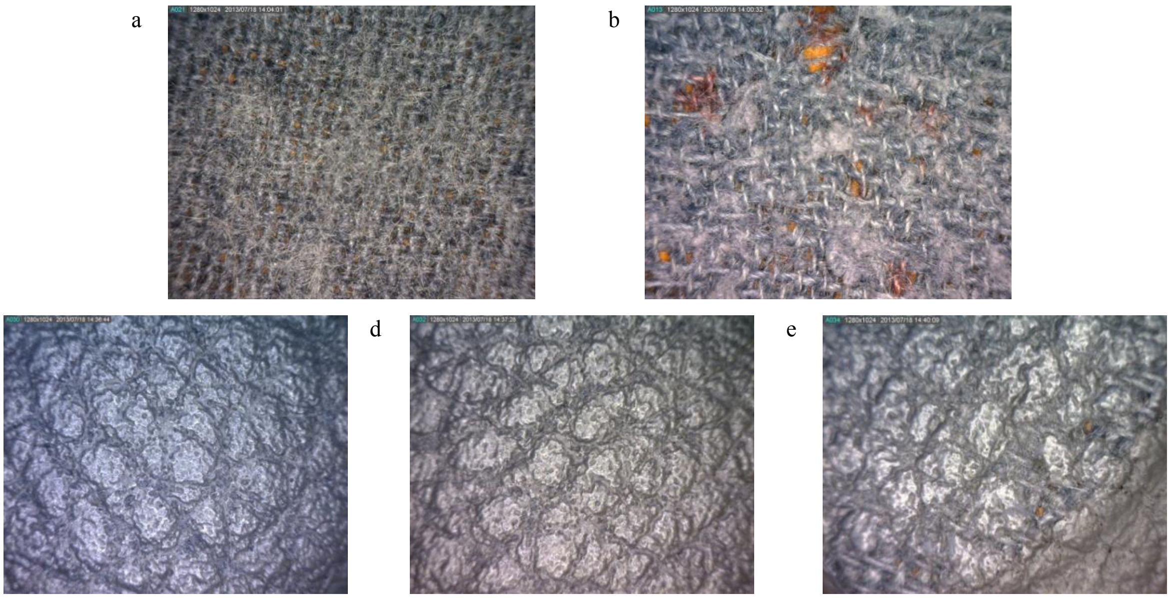
a

b

c

d

e



f  g  h 

Fig. 10.(a) basic fabric before abrasion;(b) basic fabric after 100.000 abrasion cycles;(c) coated fabric before abrasion – face side;(d) coated fabric after 100.000 abrasion cycles – face side;(e) coated fabric after 400.000 abrasion cycles – face side;(f) coated fabric before abrasion – back side;(g) coated fabric after 100.000 abrasion cycles – back side;(h) coated fabric after 400.000 abrasion cycles – back side;(Dino-Lite Pro – AM-413T5).

4. Conclusion

The aim of this study was directed towards demonstrating the impact of different warp densities on the coated fabric properties, i.e. on multicomponent materials. Analysis and comparison of basic component of material and PU coated fabric prove major influence of coating and various warp densities on changes in material properties and high correlative values. Coating increases physical-mechanical properties of materials due to utilization of aromatic polyester type of polyurethane, i.e., due to the portion of diisocyanate in PU coating, which provides greater strength, elasticity and abrasion resistance of multicomponent materials, which in turn increases the durability of the material.

The influence of warp density on physical-mechanical properties is significant. Reducing the warp density leads to a significant decrease in breaking force, elongation and abrasion resistance, while the air permeability property increases. Changes in the properties are substantially more noticeable in the basic fabric samples, than in the coated fabric samples. The biggest difference between the basic and coated fabric are visible in the abrasion resistance property, where multicomponent sample demonstrates far better properties, which is a good indicator with regard to its purpose.

Given that this study used samples from the factory Čateks, the results obtained will be presented to the factory. Thiswill provide the factory with useful information on its product, and enable further cooperation for researchers and the possibility to develop new products and improve the existing ones.

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