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CHARACTERISTICS OF COMPOUND MATERIALS FOR THE PROTECTIVE FOOTWEAR

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Abstract: *This paper presents a study on certain types of textile materials for working shoes destined for footwear upper. Thus, determinations will be made regarding the structure of the raw material and its nature, polyamide and other polyester yarns will be identified with chemical reagents. Subsequently, determinations will be made regarding the physico-mechanical properties of the materials for this type of footwear. The abrasion resistance will be determined by mass loss of the specimens subjected to friction. The air permeability of the composite materials will be determined on the basis of the pressure difference, and the water permeability is determined by the "artificial rain" method. It is worth noting that the footwear must have certain functions, also taking into account its purpose, such as protection against chemical agents, atmospheric agents, and mechanical actions. At the same time, the footwear must provide a certain microclimate for the foot to ensure its comfort during wear. In order to have a good maintenance value, leather substitutes should have functional indices close to the real leather. The quality and functionality of the protective footwear products is given by the characteristics and properties of the materials used in making them.*

Key words: *material, composite, microclimate, footwear, permeability, abrasion.*

1. INTRODUCTION

Textile materials are used more and more for the manufacture of footwear and leather goods, along with leather and artificial leather.

Thus, a wide range of composite textiles, synthetic yarns respectively, laminated with linen or diagonal linen fabrics, multilayered leather substitutes are used in the production of protective footwear.

Materials used in the manufacture of leather products must have certain characteristics which ensure both performance during use and their wear as well as during the manufacturing process. Thus, these materials must have physical characteristics, mechanical characteristics, and have a good performance towards physical-chemical agents [1].

Physical characteristics refer to geometric characteristics: length, width, area, thickness, mass, density, and transfer characteristics are those related to sanogenic indicators and refer to: water, vapor and air permeability, insulation capacity.

The mechanical characteristics refer to the ability of the materials to deform under the action of the stresses, but also to the recovery of the deformation after the ceasing of the forces. These include: tensile strength, tear strength, adhesivity on textile support, color resistance, resistance to atmospheric agents. The value of these characteristics depends on the nature of the support, in this case different fabrics are used to provide tensile strength, knits for increased flexibility, non-woven, polyurethane foams.

If textiles are used to make the upper assembly, the elongation or strength characteristics are clearly differentiated on the direction of the warp compared to the weft direction, due to the different characteristics of the warp and weft yarns respectively.

Among the physical and mechanical characteristics, which are of particular importance for the textile materials that are part of the components of the upper assembly, are mentioned: impermeability, tear resistance, abrasion resistance.

The paper presents the results of the research regarding the identification of the raw material and the physical - mechanical properties of composite textile materials used for the uppers of the protective footwear.

2. EXPERIMENTAL PART

The materials used in the experiments were taken over from SAFETY firm, which were used for certain parts of footwear upper components.

The structural analysis of the tested materials consisted in determining the thickness, mass, density and density of the yarns of the fabric.

The thickness of the materials was determined with a Louis Schopper textile micrometer with a measurement pressure rated on the mobile top disc. Reading was done with an accuracy of 0.005 mm.

The mass of composite material in g/m^2 was determined by weighing on an electronic scale of some specimens with well-known area (dimensions 5 cm/5 cm).

The technological density of yarns in fabric, expressed in yarns/10 cm, was determined by counting. The identification of yarn systems (warp, weft) was made on the basis of the difference in width criterion, according to which the warp system is more often used. This type of identification is not very certain, but it is the only way to apply it in this case.

The density of the yarns length from the fabric was determined by weighing a length of 10 cm of yarns. To eliminate the creases due to weaving, the yarn blocked in the torsiometer clips was pretensioned with a force dependent on the nature of the raw material and the yarns fineness.

Identification the raw material was done by determining the solubility of the fibers in various reagents and comparing it with the known solubility of the different fiber classes.

In the case of composite materials tested, the following characteristics were determined: resistance to abrasion, air permeability and water permeability.

The abrasion resistance was calculated by the mass loss of the specimens subjected to friction with a polyamide monofilament fabric. The pressure was made on the WEARTESTER with a press force of 1500 cN for 210 min.

The mass loss was calculated at intervals of 30 minutes according to the following equation [2], [3]:

$$p = \frac{M_0 - M}{M_0 \cdot k} \cdot 100 \quad [\%] \qquad \textbf{(1)}$$

where:

p - mass loss of the sample ;
M_0 - initial mass of the sample;
M - mass of worn sample;

k - ratio between the area actually worn and the sample surface (0.485).

The air permeability was determined on the METRIMPEX apparatus at a pressure difference of 200 Pa and a section area of the air intake of 20 cm^2.

The air permeability at the set pressure difference (Δp) is given by[4,5]:

$$P_a = \frac{q}{A} \cdot 16 \quad \text{(mm/s)} \qquad (2)$$

where: q - airflow in dm^3/min or l/min;

A - the area of the absorption exit section in cm^2;

167 – conversion factor from $dm^3/min.cm^2$ to mm/s

P_a – air permeability in mm/s.

The water permeability was determined on the METRIMPEX apparatus by the “artificial rain” method. The sample, inclined at 45° angle, was sprayed for 30 minutes with a flow rate of 750 cm^3/min.

The water permeability is measured by the water absorption coefficient, which is calculated with the relation[6,7]:

$$C_s = \frac{m_u - m}{m} \cdot 1(\quad [\%] \qquad (3)$$

where:

m_u - the mass of a square with the 10 cm side of the test material after the rain, in g;

m - the mass of a square with the 10 cm side of the tested material in conditioned status, in g..

3. RESULTS AN DISCUSSIONS

The structural analysis of tested fabrics comprises a series of characteristics, presented in Table 1.

***Table** 1 Structural analysis of composite materials*

The feature analyzed		Variant: V_1 (polyurethane foam support)	Variant: V_2 (nonwoven material support)
Thickness of composite material, [mm]		3.01	1.58
Mass of composite material, [g/m^2]		525	580.4
The yarn density in the fabric , [yarns/10 cm]	Warp	105	100
	Weft	87	87
The length density of the yarns in the fabric, [tex]	Warp	1. 157.8 (black) 2. 148,6 (beige)	153.6 (grey)
	Weft	139.8 (khaki)	153.4 (grey)
Link		Cloth	Cloth

Obs. Because of the adhesive adherent to the yarns, their density of real length is smaller.

The behavior of fibers on reagents in order to identify the raw material is shown in Table 2

Table 2. *Identification of raw material*

		Raw material colour	Reagents					
			Phenol 70 %	**Sulfuric acid 70 %**	**Dimethylformamide**	**Nitro-benzene**	**Xylene**	**Toluene**
Variant	**V_1**	**Black**	S_c	I	S_c*	S_c	I	I
		Beige	I	I	S_c*	S_c	I	I
		Khaki	S_r	S_r				
	V_2	**Grey**	I	I	S_c	S_c	I	I
		White	I	I	S_c*	S_c	I	I

S_c - soluble while boiling
S_r – soluble at room temperature
S_c*- partially soluble while boiling forming small melt balls
I - insoluble

By analyzing the behavior of the fibers in the reagents it can be stated that: the khaki yarn is made of polyamide;

- the black yarn is polyester;
- for beige and grey yarns and for white yarns in nonwoven material, its nature can not be clearly stated. If it were polypropylene, it should be soluble when boiling in xylene and toluene. Taking into account the behavior in nitrobenzene and dimethylformamide, it could be assumed that these yarns are of polyester, but this supposition is contradicted by phenol (insoluble) behavior. Therefore, because of the contradictory behavior in solvents, the nature of these yarns can not be established with certainty. One possible explanation would be that because of the age the solvents' quality has deteriorated.

Obs. *At the burning test, it behaves similarly to polyester yarns.*

The abrasion resistance, as measured by the mass loss of test specimens subjected to friction, is shown in Table 3.

Table 3. *Determining the mass loss*

Feature	**Variant**	**Stress time**			
		30 min	**60 min**	**90 min**	**120 min**
Mass loss, [%]	V_1	0	0	0,01	0.103
	V_2	0.014	0.407	0.734	1.331

Feature	**Variant**	**Stress time**		
		150 min	**180 min**	**210 min**
Mass loss, [%]	V1	0.409	0.605	0.945
	V2	1.824	2.336	2.837

Regarding the abrasion resistance of the two samples, there is an increase in mass loss over time, and if we compare them, we can say that the samples from polyurethane foam materials are more resistant to abrasion because they have a lower weight loss in time, the value being 0.945% at a friction time of 210 minutes versus the non-woven material samples. This can be seen more suggestively in Figure 1.

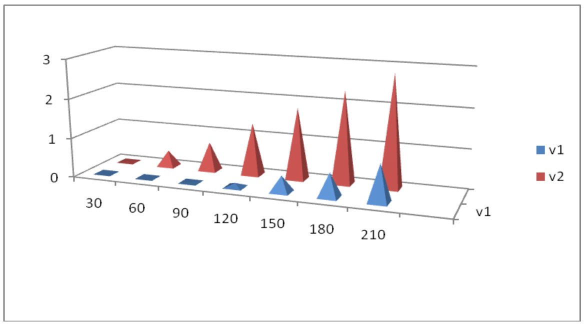

Figure no. 1 *Variation of mass loss over time*

So this material having a polyurethane foam layer can be used successfully to make uppers for protective footwear, being more resistant.

The values obtained for the air permeability of the composite materials tested are shown in Table 4.

Table 4. *Air permeability*

Feature	**Variant**	**The sense of air passage through the composite material**	
		Fabric – Layer	**Layer - Fabric**
Air permeability, [mm/s]	V_1 - polyurethane foam layer	2127.99	361.89
	V_2 - non-woven material layer	284.23	506.01

In terms of air permeability, it is observed that the passage of air from the fabric to the layer is higher for the polyurethane layer material, reaching a value of 2127.99 mm/sec, while the passage of air from the layer to the fabric has a value 361.89 mm/sec. This difference is due to the compactness of the layer that comes in direct contact with the air, but also to the structure and chemical composition, respectively to the nature of the composite.

In the non-woven fabric, the passage of air from the layer to the fabric is higher than in the case of the polyurethane foam material. So we will opt for the second material because it has better thermal insulation capacity, providing optimum comfort to the person wearing the protective footwear product made of such a type of material.

The water permeability by determining the absorption coefficient of the composite materials tested is shown in Table 5.

Table 5. *Absorption coefficient*

Feature	**Variant**	
	V_1 - polyurethane foam layer	**V_2 - non-woven material layer**
Absorption coefficient, [%]	38.17	30.18

In contact with water, higher values of the water absorption coefficient for the polyurethane foam material are observed.

It should also be noted that water has not passed through any of the composite materials tested.

4. CONCLUSIONS

The quality and functionality of the protective footwear products is given by the characteristics and properties of the materials used in making them.

As a result of the experimental research of the composite materials used for the protective footwear, the following conclusions can be drawn:

- The structural analysis of the two tested materials reveals different thicknesses, the material with a polyurethane foam layer having a higher thickness, but weighs less;
- The materials have the same type of link, namely cloth;
- The material with a polyurethane foam layer has a higher abrasion resistance than the non-woven layer;
- The non-woven material has a better thermal insulation capacity, providing optimal comfort to the person wearing a protective footwear product made of such a material;
- The two tested materials do not let through the water, the water absorption coefficient for the polyurethane foam material is higher.

The method of calculating the results obtained will be made in close connection with the production, so that the products obtained using these materials can be tested under both manufacturing and operating conditions.

5. REFERENCES

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