DEVELOPMENT AND APPLICATION OF A NEW CONCEPT OF CORK SUBSTRATE IN FOOTWEAR AND CLOTHING

A. SILVA, J. PEIXOTO, A.P. SOUTO
University of Minho, Textile Engineering Department, Campus de Azurém, 4800-058, Guimarães, Portugal
souto@det.uminho.pt

Abstract: *In the present work a "cork substrate" is developed aiming the achievement of an innovative material with ideal properties to respond to clothing and footwear applications. The preparation phases of leather processing are highly complex, with a large level of environmental aggressiveness. Garment and footwear industries are widely looking for new materials and applications able to reduce industrial pollutant charge, as well as new processes with lower water and energy consumption and higher economic advantages. Nowadays the conventional material to produce footwear is leather because it combines excellent properties such as: breathability, softness and thermal conductivity. A cork skin is laminated with membranes and textile fabrics and a comparison with leather properties has been done. The inner layer is made with a twill fabric that can be dyed and finished to confer functionalized properties. The results obtained are very promising and the possibility of using this laminated is demonstrated.*

Keywords: *Laminated cork; innovative material; process optimization; comfort; aesthetics; breathability.*

1. Introduction

The production of leather is a quite complex process that involves a sequence of chemical reactions and mechanical processes with a high environmental impact [1]. A large quantity of the leather used in footwear is processed with chromium tanning; however, this substance causes skin allergies and is highly injurious to health [2].
Cork is the bark of an Oak tree known botanically as *Quercus suber L.* [3, 4]. The cork-tree offers the advantage of being the only tree whose bark can regenerate it self after harvest, making it a truly renewable material. In terms of morphology, cork can be described as an isotropic material with close cellular structure and thin-walled cells, presenting an alveolar structure similar to a honeycomb [5]. Cork is a versatile raw material, capable of adapting to different technological processes of transformation and thus gives rise to different applications, having unique properties. It is light, does not absorb water, is compressible, impermeable to liquids and the very low thermal conductivity made it a good insulator [4].
The presented laminated cork substrate is impermeable, once the intermediate layer has a hydrophilic membrane in its constitution. The breathable membranes are polymer films impermeable to liquids, which allow vapour transmission by a molecular mechanism. Thus, the breathable membranes are able to operate as a barrier to liquid water and soil coming from the environment, allowing significant amounts of perspiration [6, 7].
A laminated fabric may be defined as a material consisting of two or more layers, where in at least one of them is a textile, bonded together by an adhesive [8]. In this study, the membrane is connected either to the fabric or to the cork.
The lamination brings two or more layers of material together in one product and is used for many different applications including apparel, shoe, home textiles and transportation.
Coating and laminating are methods to improve the physical and chemical properties and appearance of fabrics, creating the possibility to design new products, combining the advantages of different materials, such as fabrics, cork, polymers, foams and films [9].

2. Materials

The most relevant aspects related to experimental methodology will be listed in detail, materials, procedures, equipment and respective standards used for these tests.

2.1 Leather

The leather is presently considered an exceptional raw material to be applied in the footwear industry due to its excellent features. It's porous, breathable, soft and comfortable, having an excellent ability to fit the shape of the foot. The textile and footwear industries use leather mainly derived of bovine animals.

2.2 Cork

The cork is a renewable raw material with many applications in different areas, because of its unique set of properties [4]. These properties are responsible for the intense interest by footwear industry, which are: low density, compression and resilience capacity, good fatigue resistance, high impermeability and good thermal insulation [10].

2.3 Breathable membrane

The copolyamide membrane used to development the new subtract has 5µm thickness. The chemical base of the membrane applied is COPA. The properties of copolyamides include: highly breathable, abrasion resistance, good recovery, flexibility, good chemical resistance flexibility, mechanical strength and thermal stability. Table 1 shows the main characteristics of commercial membrane used in this study.

Table 1. Characteristics of breathable membrane

Melting range	165 - 175 ºC
Softening range	90 - 100 ºC
Tensile strength - MD	6.0 N
Tensile strength - TD	5.5 N
Elongation at break - MD	500 %
Elongation at break -TD	500 %

MD – Machine direction
TD – Transverse direction

2.4 Weaving fabric

Different fabrics were studied in order to choose the most suitable for this purpose. The Table 2 shows the main characteristics of the selected fabric.

Table 2. Characteristics of weave fabric

Composition	100% CO
Weave	Twill
Warp density (treads.cm^{-1})	44
Weft density (treads.cm^{-1})	22
Warp density yarn (Tex)	28.92
Weft density yarn (Tex)	27.63

3. Methods

This study was designed in order to parameterize and analyse the properties of different materials and/or combinations of materials, aiming to an ideal material to be applied in footwear and clothing with the leather's similar properties. Various tests were performed in order to verify the characteristics of the new product, including the comfort, the aesthetics, the waterproof and the breathability. Several tests were performed, including:
Water vapour permeability: according to BS 7209:1990; Thermal properties: using the device Alambeta (internal standard procedure); Air permeability: according to ISO 9237:1197; Tensile strength: according to ASTM D 5035; Pilling and Abrasion resistance: according to standard ASTM D 4966.

3.1 Water vapour permeability

Water vapour permeability was determined according to "British Standard 7209 - British Standard Specifications for Water Vapour Permeable Apparel Fabrics". According to this method the specimen under test is sealed over the open mouth of a dish containing water and placed in the standard testing atmosphere. After a period of time to establish equilibrium, successive weightings of the dish are made and the rate of water vapour transfer through the specimen is calculated. The water vapour permeability (WVP) in gm^{-2} day^{-1} can be determined by the following relation (1):

$$WVP = \frac{24M}{\mathrm{AT}} \tag{1}$$

Where *M* is the loss, in mass, of assembly over the time period (grams), *T* denotes the time between successive weightings of the assembly (hours) and *A* represents the area of exposed test fabric – equal to the internal area of the test dish (m²). The water permeability Index, *I*, is given by means of following expression (2): In which the $(WVP)_f$ is the mean water vapour permeability of the fabric under test and the $(WVP)_r$ is water vapour permeability of the reference fabric and is test in three samples, with 96mm diameter.

$$I = \frac{(WVP)_f}{(WVP)_r} \times 100 \tag{2}$$

3.2 Alambeta tester, according internal procedure of Textile Department of Minho University

For evaluation of thermal properties the apparatus Alambeta was used. The Alambeta makes an objective assessment of feeling hot/cold. This feeling is important, not only at the moment when one experiences a fabric, but when you wear any piece of clothing or footwear and during the periodic contact of internal parts of the skin with clothing. The Alambeta measures the thermal absorption capacity, that is, the touch thermal sensing any surface processing (Czech patent, produced by a German company Zweigle).
The Alambeta evaluates simultaneously the stationary thermal properties such as resistance and conductivity and the dynamic properties such as thermal diffusivity and thermal absorption.
The apparatus consists of a metal block with constant temperature (32°C) which differs from sample temperature (20ºC). When the measurement begins, the measurement head touch the lower sample surface to be measured, which is located at the base of the apparatus under the measurement head. At this time, the surface temperature of the sample changes abruptly and the apparatus records the evolution of heat flow. This apparatus evaluates various parameters, such as:

• **λ** (10^{-3}) - thermal conductivity (stationary or dynamic property - W m^{-1} °K),expresses the amount of heat flowing through the material per unit of length. Thermal conductivity is the capability of a material to transfer heat among two surfaces with different temperature;
• **r** (10^{-3}) - thermal resistance (prop. stationary – m^{2} °K W^{-1}), expresses the resistance offered by a material to heat flow: the ratio between the thickness and thermal conductivity;
• **h** (mm) thickness of the material.

3.3 Air permeability

For this test we followed the principles of the NP EN ISO 9237:1997 - Air Permeability of Fabrics, it was used the air permeability tester TEXTEST FX 3300. This equipment allows forcing air through the material under test, determining a pressure difference between the two faces thereof. The test allows to determinate the air permeability of the materials, by quantifying the flow rate of air that traverses each sample.

3.4 Tensile strength

The equipment brand Hounsfield H10 KS model was used to study this property. Test was carried out according to ASTM D 5035 - Breaking Strength and Elongation (strip force). In this method the total width of the specimen is fixed 50mm, initial length of the samples is equal at the distance between clamps of the tensile machine i.e. 200mm. The test is carried out with a pre-tension of 5N.

3.5 Pilling and Abrasion resistance

The abrasion resistance was evaluated with Martindale Tester, according to standard ASTM D 4966. The abrasion resistance is estimated by weight loss mass of the samples, or broken yarn. The specimens to abrasion test are 38mm area the test is evaluated with a pressure of 9KPa. The test ends when yarn breaks off. The formation of pilling is evaluated visually after defined intervals of the number of frictions. According with this standard the number of 5000 cycles are performed for four specimens per sample. The evaluation is made comparing the specimens with standard photographs, these are classified on a scale of 1 (very pilling) to 5 (no pilling).

4. Results

4.1 Water vapour permeability

The tests were performed in the laboratory with standard atmosphere, that is, 20 ± 2°C and 65 ± 2% relative humidity and were tested three specimens for each sample.
Comparison between leather and the new laminated cork substrate were made and water vapour permeability results can be observed in Figure1.

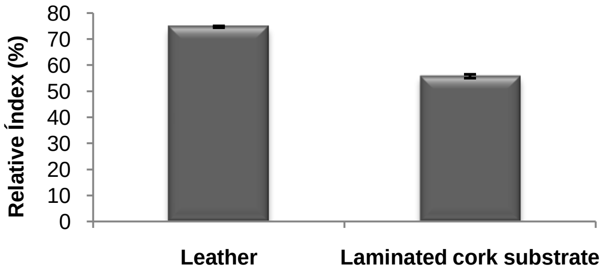

Figure 1. Water vapour permeability of leather and laminated cork substrate

The property of water vapour permeability is higher in leather than in the laminated cork substrate, around 25%, and the standard deviation for both materials is low, 0.35 and 0.74 respectively.

4.2 Thermal conductivity

This property was determinate according an internal procedure of Textile Department of Minho University, the value shown in Figure 2 is obtained from the average of five measurements.

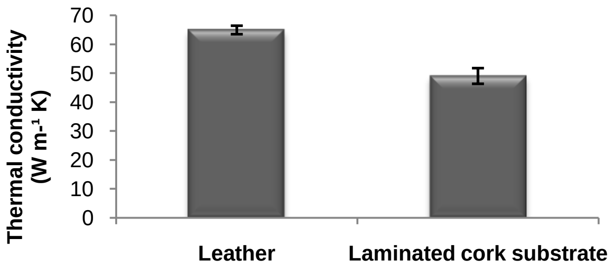

Figure 2. Values of thermal conductivity of leather and laminated cork substrate

The laminated cork substrate is the material that presents a better insulation characteristic. The innovative material shows excellent properties to be applied in footwear. In the Figure 2 the standard deviation values are 1.47 and 2.71 respectively.

4.3 Air permeability

The values shown in Table 3 correspond to a mean value of 10 tests for each material. The test conditions are: area of measurement was 20cm² and a pressure of 200Pa.

Table 3. Air permeability

	Leather	Laminated cork substrate
Air permeability (L m^{-2} s^{-1})	0.780	0.567

It is possible to verify that laminated cork substrate has lower air permeability when compared with leather.
Low air permeability is very important property to apply in cloths and footwear, because protect the user from the win. Nevertheless the values obtained are very low.

4.4 Tensile strength

For tensile strength 10 samples for each material were tested, 5 for longitudinal/warp direction and 5 for transversal/weft direction. The test conditions were: samples with 50mm width and 200mm length. The distance between grips was 200mm the test speed was 100mm/min with a pre-load of 2N.

It's possible to observe the comparison between tensile strength and extension results of leather and cork substrate. The Figure 3a) shows breaking strength and 3b) extension.

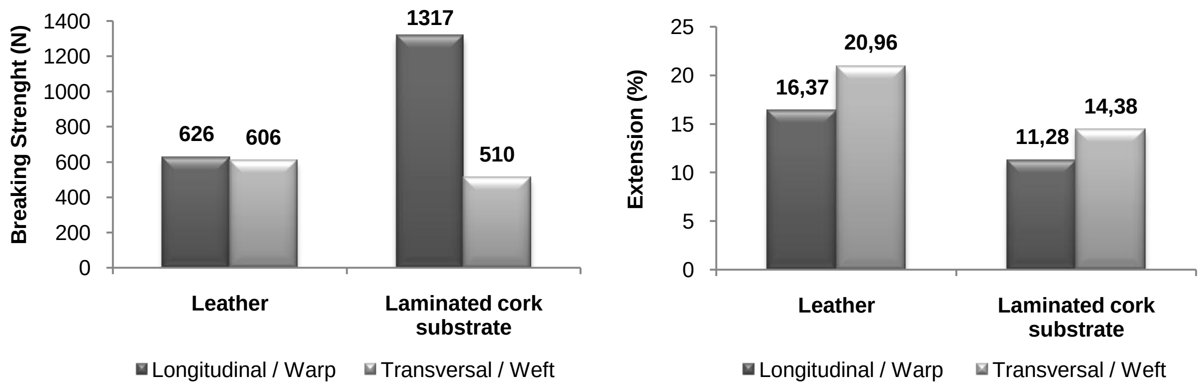

Figure 3. Results of Breaking strength a) and Extension b) of leather and laminated cork substrate

It's possible to verify that the laminate cork substrate in warp direction have a higher tensile resistance (+110%) and in weft direction have lower (-16%) than leather. The leather has very similar tensile strength in both directions.
To the extension it is noticeable that the studied material has a lower extension when compared with the leather, in both directions.

4.5 Abrasion resistance

The twill fabric, one of three layers, was tested to pillig formation and abrasion.

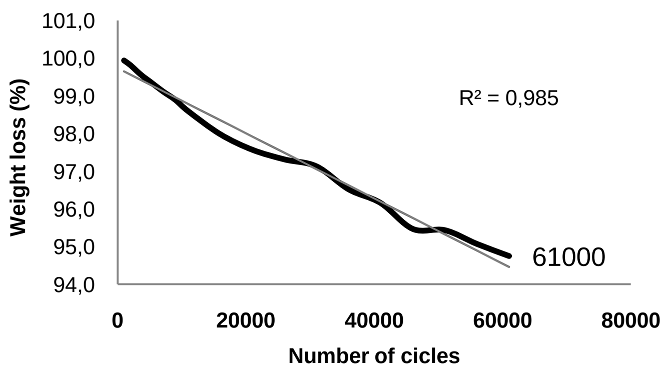

Figure 4. Abrasion resistance of the fabric used in the laminated substrate

The material obtained rated the value of 5, i.e., no pilling formation. It can be observed in the Figure 5 that the material yarn broken at 61000 cycles, and the percentage of weight loss is around 5%. The twill fabric present linear relationship in weight loss, the correlation is very high, i.e. more than 98%.

4.6 Laminated cork substrate - three laminated (cork with membrane and weave fabric)

The Table 4 shows the results of different materials used. The laminated cork consists of three materials, namely, a twill fabric, a breathable membrane and cork. These can be analyzed and compared with leather.
The results obtained show that the new material has the same thermal properties the leather. The laminated cork substrate has a tensile strength higher in warp direction. The fabric in laminated cork substrate obtained has excellent results in the abrasion and pilling tests.

Table 3. Characteristics of laminated cork substrate

	Leather	Cork	Weave fabric	Breathable membrane	Laminated cork substrate
Weight per unit area [gm^{-2}]	976	89	198	-	300
Thickness [mm]	1.60	0.47	0.52	-	0.85
Water vapour permeability [%]	74.72	74.73	98.09	96.87	55.75
Thermal resistance [m^2 °K W^{-1}]	0.02	0.01	0.01	-	0.02
Thermal conductivity [W m^{-1}°K]	0.06	0.04	0.05	-	0.05
Air permeability [L m^{-2} s^{-1}]	0.78	360.7	69.73	0	0.567
Breaking force – longitudinal/warp [N]	606	-	1271.4	-	1317.0
Breaking force – transversal/weft [N]	626	-	524.8	-	510
Elongation at break – longitudinal/warp [%]	20.96	-	10.57	-	11.28
Elongation at break – transversal/weft [%]	16.37	-	11.32	-	14.38
Abrasion resistance [cycles]	-	-	-	-	61.000
Pilling [degree]	-	-	-	-	5

5. Conclusions

In this context it can be said that this laminated cork substrate presents characteristics very similar to leather. It is possible to use this laminated cork substrate with a breathable membrane for clothing and footwear. The new substrate is impermeable and it has very good insulation and once it's made with a twill fabric new design opportunities are possible, for instance anti-bacteria and anti-fungi treatments to decrease proliferation of microorganisms in footwear.
Nowadays, this new laminated substrate can be already used in textile industry, but the next aim of this study will be to increment the abrasion fastness of the cork so it can be used in the footwear industry. Then a new green product has been design, a real cork skin.

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