International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
www.allsubjectjournal.com
Volume 4; Issue 2; February 2017; Page No. 64-68

Water vapor permeability and dimensional stability of leather after cyclic mechanical treatments

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Abstract
Studies are reported about leather after wearing, as leather experience various long-lasting deformations during manufacturing processes and wearing lifetime. Stress due to wearer movement is focused in different portions of leather garments such as knee, elbow, back line, seat, opposite shoulders etc.

Goat and sheep leathers are investigated in this study, as they are the most popular leathers used in clothing field. The comparison of the dimensional change and water vapor permeability of sheep and goat leather is presented after different fatigue cycles and durations. Predicting the change of leather nature after fatigue cycles will improve designing of leather garments to provide comfortability and ergonomics to the wearer. The maximum number of stretching cycles was 260, and elongation percents varied in the range of 5%-25%. Goat leather has high recovery after stretching than sheep leather.

Comparing the results obtained of water vapor permeability, it was observed that sheep leather has higher percentage than goat leather. The decrease in the water vapor permeability of leather after a cyclic stretching was also reported. Three clothing designs are executed by adobe photoshop software proposed to produce with suitable leather type.

Keywords: leather, dimensional change, water vapor permeability, comfort

1. Introduction

Leather is one of the most usable and important materials in different fields (such as clothing, furniture, automotive upholstery, etc) [1]. Leather garment s are mainly made from sheep, goat and cow napa [2].

Leather is the skin of animal. The fibrous skin structure varies considerably between skins of different species and types within species, thus giving the leather industry a wide variety in raw materials. The mammalian skin has distinct layers; the layer which extends from the outer surface to the base of the hair roots is termed the grain layer. In the underlying corium; the fiber bundles are considerably larger and interweave at a higher angle relative to the skin surface. Towards the inner or flesh surface; the fibers become finer and run in a horizontal plane to form a limiting or flesh layer, separating the skin from the underlying muscles [3].

The natural fibrous weave of leather gives its unique physical properties of handle and ability to accommodate to the stresses and movement subjected during its use. The total comfortability of the leather apparel on wearing depends on many factors as permeability to water vapor, water proof and wind proof. In this work, an attempt has been made to study one of the prime comfort parameter "water vapor permeability".

The wear comfort is important qualitative criterion that affects performance, efficiency and well- being of human [4]. The water-vapor permeability is a critical factor of wear comfort, especially in conditions that involve sweating. This property allows the fabric to be water-vapor permeable, to have protection against wind and to be waterproof [5, 6].

Primarily, leather apparels are used for protection against cold conditions. Understanding the performance of leather in the final product form (apparel) gives precious inputs for the design and manufacture of the leather apparel. Designing of leather garments plays a major part in providing comfort ability and ergonomics to the wearer. More accurate and specific inputs in the design step leads to ergonomically designed garment. Measuring a material's reaction to conditions of use provides information that can be used to predict product performance [7]. Water vapor permeability is one of the most important physical properties of leathers, which may greatly affects the breathability and the comfortable feelings of leather goods. There are great numbers of capillaries among collagen fibers in leathers as well as plenty of hydrophilic groups on the collagen chains. They may confer leathers with good water vapor permeability, compared with other synthetic clothing-materials. Because of the complexity of leathers and the uncertainty of affecting factors on the water vapor permeability of leathers, it is difficult to study the permeability to water vapor of leathers and few studies are reported in this field [8].

It has been widely known that shoes and garments must be water vapor permeable, or breathable, and to be comfortable. This breathability allows perspiration to evaporate promptly when activity level increases; there with the heat generated by metabolism can be continuously dissipated and regulated, protecting against a damp and roasted feeling. Leather has been used for the manufacture of shoes and garments since centuries. Generally speaking, unfinished leather has high water vapor permeability (WVP) because of its natural porous structure. But in order to modify the shade/gloss/ handle, improve its physical properties (such as light/rub fastness and resistance to water/solvent/ abrasion), and hide any defects or irregular appearance, leather needs to be finished [9].

Leather consists of interconnected microspores, the diameter of which is a hundred times smaller than the diameter of water drops (the diameter of water drops is not smaller than 200 µm), but a hundred times larger than a molecule of water vapor (which is usually smaller than 0.0003 µm). This structure allows the passage of perspiration vapor to the outside, and at the same time blocks the entry of rain and snow [10, 11].

Goat and Sheep leather are preferred in apparel production due to their suitable thickness and weight compared with other leathers like cows and buffalos which are comparatively thicker and heavier, therefore they are preferred in shoes and bags [12]. Leather clothes during wear undergo a multiplex cyclic deformation and stretching due to the wearer movement. Stress due to wearer movement is focused in different portions of leather garments such as knee, elbow, back....etc. During the mechanical treatments, leather sustains deformations that change its structure affecting their dimensions and permeability to water vapor. During wear, the structure of leather is damaged irreversibly and might be considered undesirable in apparel applications.

In the present study, we attempted to show the dependence of dimensional stability and water vapor permeability of goat and sheep leather on cyclic stretching parameters.

2. Experimental

2.1 Materials and methods

2.1.1 Leather specifications

Two types of leathers were examined (Goat leather & Sheep nappa) which are the most leathers used by manufacturers within leather apparel industries. The leathers specifications are listed in table 1.

Table 1: Characteristics of the examined leathers.

Leather type Property	Sheep leather	Goat leather
Thickness	1 mm	1mm
Mass per unit area (g/m$^{2)}$	460 gm/m^2	330 gm/m^2
Tensile strength (kg/cm$^{2)}$	96.68	58.86
Dry/wet abrasion	good	good
Color fastness test	4	4

2.1.2 *Determination of dimensional change*

Specimens 10×10 cm of sheep and goat leather are subjected to different stretching cycles: (percents, and durations), by fixed elongation method; the reading is average of four reads. All tests were carried out after the specimens were conditioned in standard atmospheric conditions (temperature 20 ± 2 °C, 65 ± 2 % relative humidity).

After the specimens had been stretched for (n) hours the tension was released, then the length of the specimen was measured under zero stress after it had relaxed for 8 hours, in order to find the dimensional change percentage of the materials.

Dimensional change (D) was assessed by the Eq. (1):

$$D(\%) = \frac{A-B}{A} \times 100 \quad (1)$$

Where A is the length after stretching, B is the length before stretching.

2.1.3 *Determination of water vapor permeability*

The water vapor permeability points to the ability to make water vapor penetrate from air of the larger humidity to that of the minimal one. Owing to the water vapor permeability, the gas and water vapor of the wearers can be eliminated. Therefore, water vapor permeability is usually used to characterize the properties of leather [13].

Water vapor permeability is measured in mg/1000 mm^2, according to Egyptian standard test methods number 275/2007(apparel and gloves leather), environmental conditions: temperature 23 C°& relative humidity 52%.

2.1.4 Colour fastness test

Color fastness is measured according to gray scale and EOS 122/2008 by Ministry of industry& Foreign Trade, environmental conditions: temperature 23 C°& relative humidity 55%.

3. Results and discussion

3.1 Dimensional change

The load-elongation and recovery behavior of leather show considerable variations due to the differences in the structure [11].

3.1.1 Effect of fatigue (stretching cycles) durations on dimensional change

Goat and sheep leather specimens are subjected to different durations of stretching at fixed elongation 20 %. The dimensional changes for both length and width are assessed and represented in figure 1 and 2.

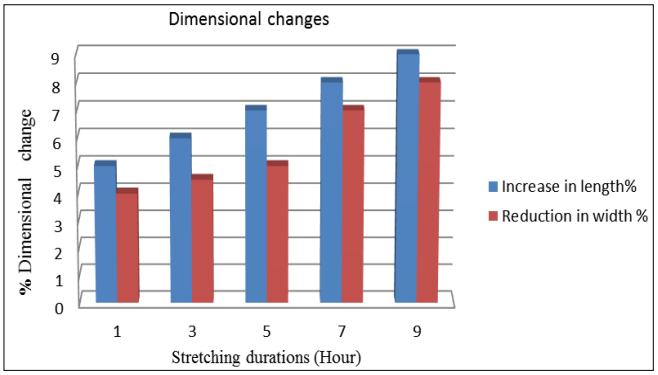

Fig 1: Dimensional changes of sheep leather after different stretching durations

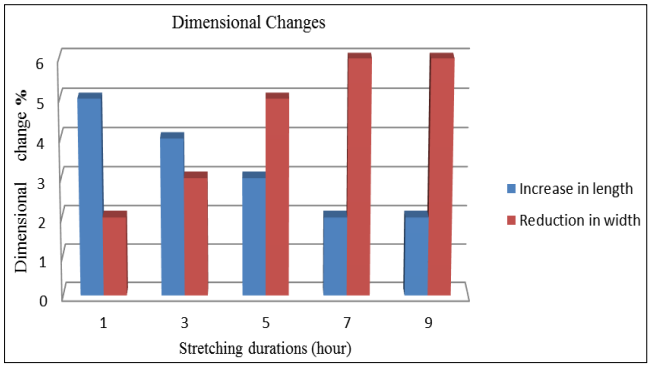

Fig 2: Dimensional changes of goat leather after different stretching cycles.

On subjecting leather to mechanical treatments, it undergoes deformations to variable extent. Sheep leather is subjected to more deformation than in goat leather in case of long time of stretching. As when the two types are sustained stretching for one hour, length increased nearly 5% for both types. And when the two types are sustained stretching for 9 hours, leather length is increased 9% and 2% for sheep and goat leather respectively.

Generally in leather when fine spaces remain between fibrils and fibers they are free to move over each other within the fiber bundle and within the fiber weave as a whole. This permits the leather to accommodate to stretching, compression or creasing [3].

3.1.2 Effect of number of stretching cycles on dimensional stability

Goat and sheep leather specimens are subjected to different numbers of stretching cycles (50, 70, 90, 180, and 260) at fixed elongation 20 %. After stretching done, the dimensional changes (length and width) are assessed and expressed in figure 3 and 4.

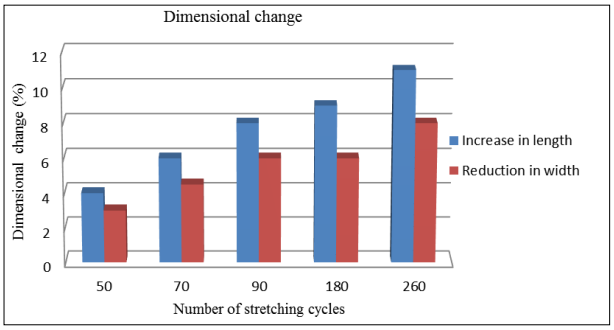

Fig 3: Dimensional changes of sheep leather after different stretching cycles.

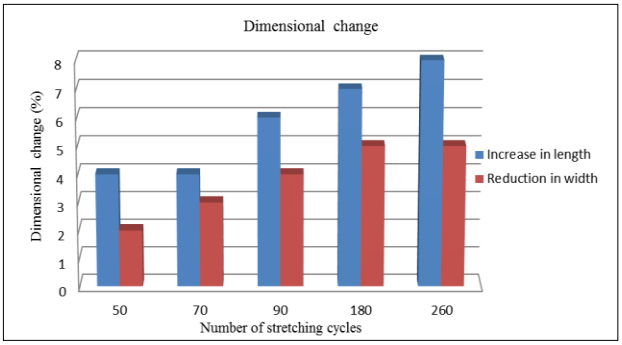

Fig. 4: Dimensional changes of goat leather after different stretching cycles.

On subjecting leather to different stretching cycles ranging from 50 to 260 cycles, It was noticed that goat leather has more recovery after stretching as it reach approximately to 8% increase in length compared with 11% in case of sheep leather after subjecting to 260 stretching cycles.

3.1.3 Effect of stretching Percentage on dimensional changes

Goat and sheep leathers are subjected to different percents of stretching ranging from 5-25%. Increase in length accompanied with reduction in width is assessed to determine dimensional changes of each leather type. Data are represented in figure 5 and 6.

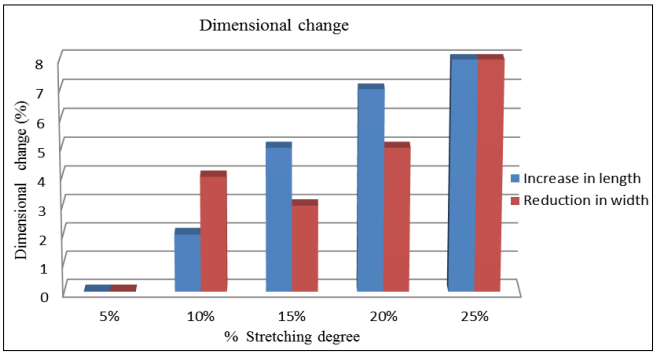

Fig. 5: Dimensional changes of sheep leather at different stretching cycles.

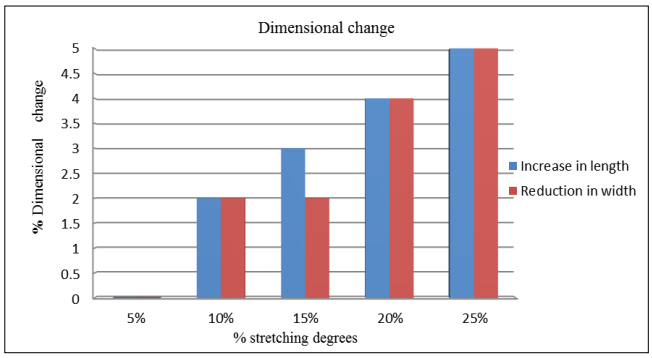

Fig. 6: Dimensional changes of goat leather at different stretching cycles.

After goat and sheep leather has subjected to different percents of stretching. It was noticed that by increasing stretching percents over than 5% increase in length accompanied with reduction in width occurs.

In general goat leather has more recovery after stretching than in sheep leather. This may be due to in goat skin the hairs wide spacing allows for smooth interweaving of the corium fibers into the grain layer and there is no discontinuity between the two layers. The corium fiber bundles are relatively fine and interweave compactly at medium angles so fibrils and fibers are free to move over each other within the fiber bundle and within the fiber weave as a whole.

Otherwise in sheep skin the density and curl of the wool fibers within the grain layer limits the space through which the corium fibers can interweave into the grain layer and there is a propensity to looseness at the junction between the two layers. In addition, natural fat tends to be stored in a layer of fat cells at the junction between grain and corium. These fat cells interrupt the fiber weave still further and after the fat has been extracted during leather processing, the collapsed fat cells add to the looseness in this region [3]. So sheep leather in stretching tends to deformed irreversibly.

3.2 Water-vapor permeability

The effect of stretching cycles and durations on water vapor permeability is discussed for both goat and sheep leathers and showed in tables 2 and 3.

3.2.1 Effect of stretching cycles on water vapor permeability

Goat and sheep leather specimens are subjected to different numbers of stretching cycles (50, 70, 90, 180, and 260) at fixed elongation 20 %. After stretching done, the water vapor permeability is assessed and expressed in table 2.

Table 2: Water vapor permeability of both goat and sheep leathers in relation to different stretching cycles.

Stretching cycles	Goat leather	Sheep leather
0	1272.7	2368.7
50	883.8	1920
70	919.2	1944.4
90	954.5	2050.5
180	989.9	2070.5
260	999	2227.3

3.2.2 Effect of stretching durations on water vapor permeability

Goat and sheep leather specimens are subjected to different durations of stretching at fixed elongation 20 %. Water vapor permeability is assessed and represented in table 3.

Table 3: Water vapor permeability of both goat and sheep leathers in relation to different stretching durations.

Treatment (hour)	Goat leather	Sheep leather
Zero	1272.7	2368.7
1	813.1	1555.5
3	989.9	1661.6
5	1131.3	1944.4
7	1166.6	2545.5
9	1185.6	2580.8

Fatigue and stretching cycles on leather have the ability to change porosity nature and structure. The porosity of leather has a great influence on water-vapor permeability. As when the pore size is increased the water-vapor permeability is also increased.

Fatigue and stretching cycles on leather have the ability to change porosity nature and structure. The porosity of leather has a great influence on water-vapor permeability. As when the pore size is increased the water-vapor permeability is also increased.

Tables 2 and 3 revealed that the blank sheep leather is superior in water vapor permeability (2368 mg/1000 mm^2) than in blank goat leather (1272 mg/1000 $mm^{2)}$.

This is due to the natural structure of goat skin is more compact than sheep skin. The more compactness structures of the skin the more difficult to water vapor to pass through.

In sheep leather the corium fibers are fine and less compactly interwoven than in the goat leather. This allows the leather to be more soft and drapeable; qualities required of clothes leather and this is why sheep leather is more water vapor permeable than goat leather.

When leather is elongated the angle of weave falls and the structure becomes more compact as spaces within the structure are reduced [3]. In both goat and sheep leathers the water vapor permeability is decreased by increasing stretching percents and durations. This decrease in permeability of water vapor is due to increase in length accompanied with reduction in width cause compactness in structure and pores of the skin to be closed.

3.3 Proposed designs

By using adobe photoshop software (photoshop CS version 8), three clothing designs are executed. Color palettes of each design are also introduced by photoshop. Each design is proposed to produce with suitable leather type.

Fig 7: Design 1 and 2 with their color palettes

3.3.1 Design (1)

Is consisting of two pieces top piece is bronze and the bottom is eggplant color (figure 7). Using bronze, and eggplant colors, gives a calm transitional style. The jacket proposed to produce from sheep leather, as the closed jacket will be permeable to water vapor. Goat leather is the best choice to produce the skirt due to high recovery after stretching, as it is fitted so it will stretch comfortably in accordance with body movements. The whole design is symmetrically balanced contributes to a unified aesthetic effect.

Vertical lines in this design lead the eye move up to down with the feeling of tall and thin, also horizontal lines are more static and tranquil therefore calmer and more passive.

3.3.2 Design (2)

The color of the coat is redorange as showed in figure 7; it is sunny and cheerful warm color. The upper coat is proposed to produce from sheep leather, as the coat sustains less tension and stretching due to its wide measurements. Also it will be worn over, so it needs to be high permeability to water vapor. The most common lines in this design are; vertical lines which evoke strength and power and lead the eye moves up to down. Harmony is achieved with the visual texture resulted from using fur with leather.

Fig 8: Design (3) with the color palette

3.3.3 Design (3)

The colors of the design are cerise, grey and black as shown in figure 8. Using fur with leather work together to complete harmony in the whole design. Using leopard prints by adobe photoshop software in the bottom piece draw attention and give emphasis to the whole design.

4. Conclusion

1. This paper aims to predict the behavior of leather after different mechanical treatments. The studied leather types are goat and sheep leather, which are the most popular used in apparel field.
2. Goat leather has more recovery after stretching than in sheep leather.
3. In both goat and sheep leathers the water vapor permeability is decreased by increasing stretching percents and durations. Comparing the results obtained of water vapor permeability, we observed that sheep leather has higher percentage than goat leather. The decrease in the water vapor per¬meability of leather after a cyclic stretching test was also reported.
4. In designing of leather garment it should take into account, that goat leather is more suitable for fitted pieces due to high recovery after stretching, while sheep is more suitable to coats and jackets as it more permeable to water vapor.

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