Effects of External Forces on the Structure and Properties of Aluminum Retanned Chrome-Leather

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Abstract

There are different kinds of external forces exerting on hide and leather during the leather making. The structure and properties of the leathers may be changed in response to these force actions. In this work, drying and finishing process were simulated in laboratory and different forces were applied on aluminum chrome cow leather so that they were in a different stress states, i.e., uniaxial stress state and plane stress state.

Tensile tests were performed using leather strips to observe their deformation, creep and failure. The results showed that after drying and stretching treatment, the yield of leather increased for both uniaxial and plane stretching mode, while the mechanical properties of the samples were improved with the increase of stretching strain.

Mechanical softening processing may improve the mechanical properties. It can increase both the tensile strength and the elongation at break of leather, while the porosity is decreased. A simple model of the effect of forces was proposed to describe the change in structure and properties of leathers.
Key words: External Forces, Structure, Properties, leather, Aluminum Retanning

1. Introduction

Collagen is the most abundant renewable polymer produced from animals. Since the dawn of human civilization, collagen materials such as leather have been among the most dominant natural fibrous materials used by mankind, especially for clothing, upholstery, and shoes. Leather is economically significant because it is a major by-product derived from the meat industry. Although chromium salts are still largely used as tanning agents in tanneries, chrome-free leathers are studied because of the environmental aspects for the pollution of chrome related problems (C K Liu. et al. 2010). In the aluminum retanning process, high basicity of aluminum chloride or aluminum sulfate are usually used. By aluminum retanning, leathers may be provided with a tight, delicate, and smooth grain, and a poor ductility (Musa A E.et al. 2012).

In the process of tanning, leather will be affected by a variety of external forces when it is squeezed, stretched, soften, dried, and etc. The responds of leathers to the stress applied on them can

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determine some of its important properties, such as yield ratio, mechanical properties (tensile strength, breaking elongation, etc.), and flexibility. Besides, it will affect leather's behavior during post process. So studying the mechanical response of leather in tanning process theoretically has always been the scholars' expectation (Attenburrow G E. 1992).

Yield of leather is an important index to measure the economic benefits of leather since it is sold by area. So how to increase the yield and not decrease the quality of leathers is highly concerned by the leather maker (Wright D M. et al. 2000). As a material, mechanical properties of leather are extremely important when it is processed and used. Elongation at break represents the softness of leathers, tensile strength represents whether is strong enough. So the quality and the mechanical properties of leather are closely related the application of leathers (K Y Tang. 2012). Many unique properties of leather are related with its vast natural micropore. The water vapor permeability of leathers may be provided by its continuous micro cellular network, and its bending fatigue resistance is due to its microporous structure of fine fiber that can be redirected against pressure which keeps the air inside the porous structure, thus making the leather with high insulation. All of these are needed by the shoes and clothes, making porosity an important indicator of leather (Ciliberto A. Cavaccini G. Salvetti O. et al. 2002).

In the present work, after being chrome tanned, the wet blue were aluminum re-tanned, neutralized and fat liquored. To imitate the leather drying and finishing processes, the leathers were applied in different stress states with different strain, i.e., uniaxial stress state and plane stress state. Some samples were mechanically softened. Finally the mechanical properties, porosity, the yield of the leathers were studied. The results show that uniaxial and plane stress tensile performance can improve the mechanical properties, the yield of the leather as well as the porosity, and mechanical softening can improve both the tensile strength and the elongation at break, while the porosity was decreased.

2. Material and Methods

2.1 Major experimental materials and equipments

Chrome-tanned leather, wet blue was from the Heitianmingliang tannery，Xinxiang, China. Five roller tanning machine, DJDø350, was from Dongbeitang leather Machinery Factory, Xishan, China. SANS Computer-controlled electronic universal testing machine, Shenzhen sans Measurement Technology Co., Ltd. The mechanical tensile analog instrument was made by us in our laboratory.

2.2 Preparation of test samples

After being chrome tanned, the wet blue was aluminum retanned, neutralized, and fat liquored to yield different samples.

2.3 Simulation of mechanical stretching

Simulation of uniaxial stretching: Four leather samples were studied. A square sign was made in the samples to measure the change of length and width of the square after stretched. Control the size of strain of 5%, 10%, 15%, and 20%, use the uniaxial stretching device as shown in Figure 1. The samples were unloaded after being dried in an oven for 3 hours, and the change in length and width were measured after 6 hours. Finally, half of each sample were mechanically softened.

Simulation of plane stress state: Four leather samples were studied. A square sign was made in the samples to measure the change of length and width of the square after stretched. Control the size of strain of 5%, 10%, 15%, and 20%, use the plane stretching device as shown in Figure 2. The samples were unloaded after being dried in an oven for 3 hours, and the change in length and width were measured after 6 hours. Finally, half of each sample were mechanically softened.

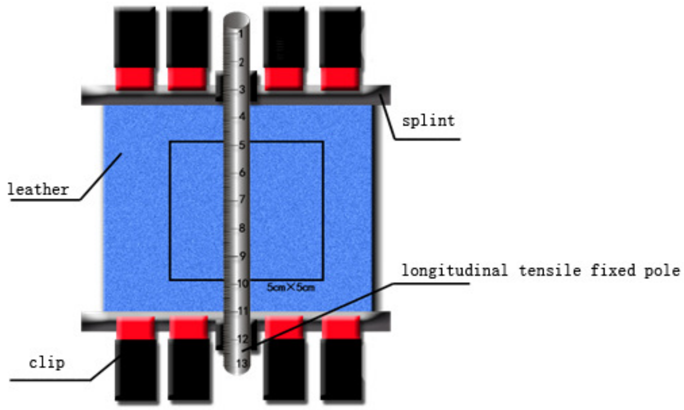


Figure 1. The simulation device of uniaxial stretching

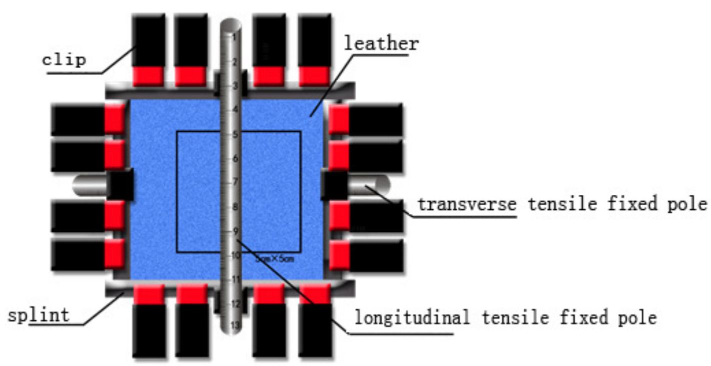


Figure 2. The simulation device of biaxial stretching

2.4 The yield of samples

Mark a square with the dimension of 5cm×5cm on the leather. After being stretched and dried, the samples were measured to get the change of length and width of the square.

2.5 Tensile behaviors of the samples

SANS computer-controlled electronic universal testing machine was adopted to measure the mechanical properties of the different samples. Standard samples were prepared by standard dumbbell-shaped tool. Micrometer caliper was used to measure the thickness (about 0.9mm~1.0mm) and width (about 4.0 mm) of the samples. On the basis of GB/T 1040.3-2006, tensile experiment was taken by assay method of the tensile properties of films and sheets, with the minimum force of 0.01N, the scale length of 20mm, and the stretching speed of 100mm/min.

2.6 The porosity of samples

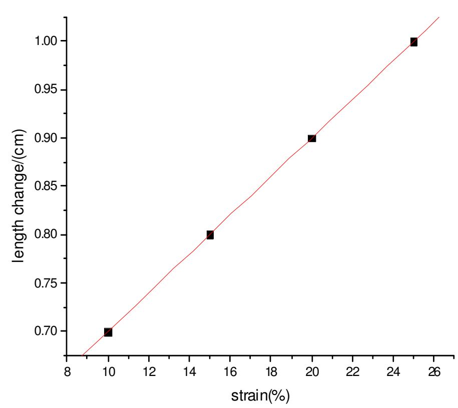
The samples were cut into the narrow rectangle shape with the dimensions of 5mm and 2~3mm, and the scraps attached on the samples were carefully removed. 3 ~ 5g of samples were used. The standard method was adopted to determine the porosity with a certain volume of volumetric flask and toluene.

3. Results and Discussion

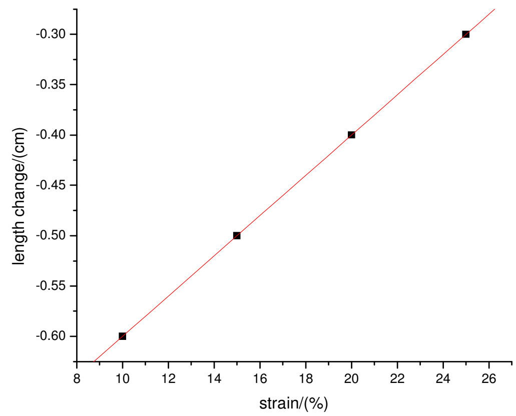
3.1 The change of yield of samples

Chart 1. Dimensional changes of samples during the experimental process

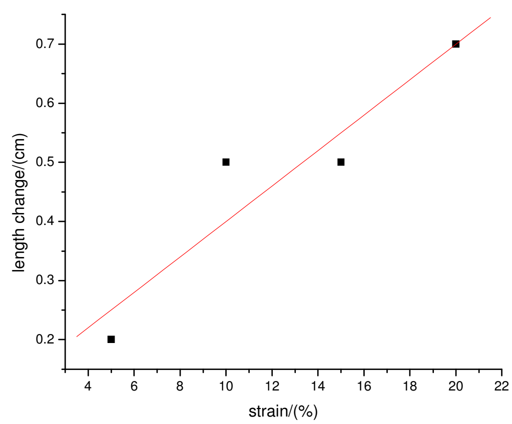
	Strain (%)	Processing time(h)	Temperature(□)	Stress state	Changes of the sign along the backbone	changes of the sign perpendicular to the backbone
1	10	3	40	uniaxial	0.7	-0.6
2	15	3	40	uniaxial	0.8	-0.5
3	20	3	40	uniaxial	0.9	-0.4
4	25	3	40	uniaxial	1.0	-0.3
5	5	3	40	plane	0.2	0.1
6	10	3	40	plane	0.5	0.3
7	15	3	40	plane	0.5	0.4
8	20	3	40	plane	0.7	0.7



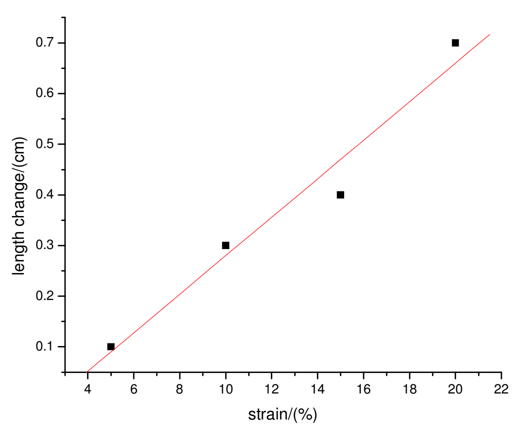
(a) Linear fitting of the strain and the change along the backbone after uniaxial stretching



(b) Linear fitting of the strain and the change perpendicular to the backbone after uniaxial stretching



(c) Linear fitting of the strain and the change along the backbone after plane stretching



(d) Linear fitting of the strain and the change perpendicular to the backbone after plane stretching

Figure 3. Linear fitting of the strain and the change in different stress states with different strain

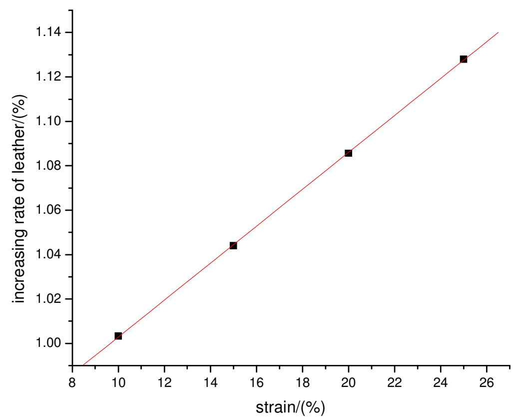


Figure 4. Linear fitting of the strain and yield of samples after uniaxial stretching

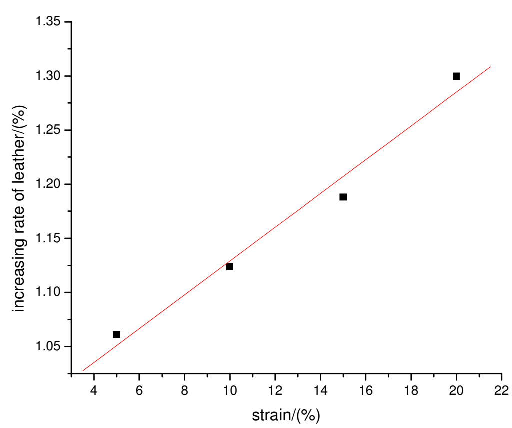


Figure 5. Linear fitting of the strain and yield of samples after plane stretching

From Figure 3 and 5 we know that it shows a linear relationship between the deformation and the strain of the samples both in the uniaxial and plane stress state, especially the former.Meanwhile there is a linear relationship between the yield and the strain , i.e yield of the samples increased with increasing strain applied to the samples.

3.2 Mechanical properties

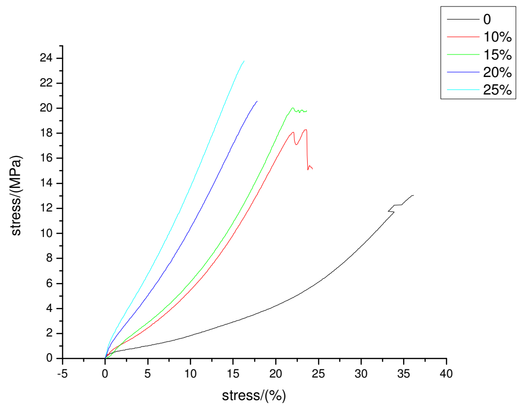


Figure 6. Stress-strain curves of the samples processed in different uniaxial stress state

Figure 6 shows that both the tensile strength and the young modulus of the samples were improved with increasing the external forces after uniaxial stretching, while the elongation at break of the samples were decreased. The reason might be because that the internal molecular in the samples have oriented, leading to the increase of the tensile strength and the young modulus. The internal molecular chains have already extended with a highly oriented fiber structure. All the fibers were aligned mostly in one direction to make the samples stiffer, probably the phenomena of stress focus appeared. So the elongation at break of samples was found to be decreased.

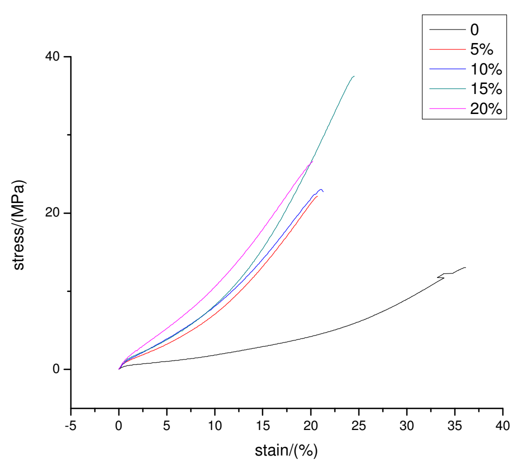


Figure 7. Stress-strain curves of the samples processed in different plane stress state

Figure 7 indicates that the tensile strength was markedly increased after the plane stretching except for the sample of 15%. Both the tensile strength and young modulus were improved with the external forces increasing, while the elongation at break of the samples was decreased, probably because of the fibers aligned in one direction to make the samples stiffer.

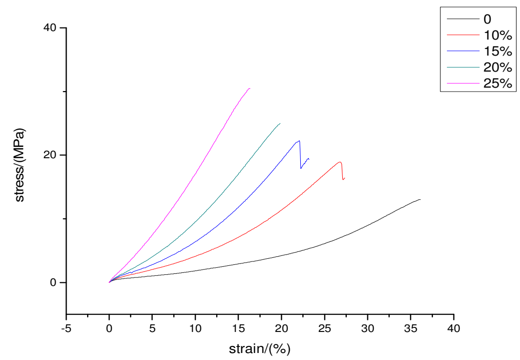


Figure 8. Stress-strain curves of the uniaxial stretching samples after mechanically softening

Figure 8 shows that both the tensile strength and young modulus of the samples were improved with increasing the external forces, while the elongation at break of the samples was decreased. From Figure 6 and Figure 8, we know that both the tensile strength and the elongation at break of the mechanically softened samples were generally greater than the corresponding controlled samples, i.e., the ones just stretching. This is mostly because stress focus occurred on the samples before the mechanically softening. Both the tensile strength and the elongation at break were improved after mechanically softening, and the reason is probably that some part of the stress focus disappeared.

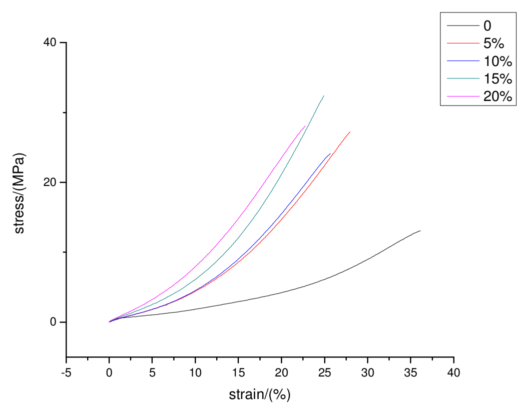


Figure 9. Stress-strain curves of the plane stretching samples after mechanically softening

Figure 9 shows that the tensile strength of the samples being stretched and mechanically softened was improved dramaticlly. The young modulus was improved with increasing the external forces, while the elongation at break was decreased. The disappearing of the stress focus after the mechanically softening might be the main reason of this phenomenon. The disorientation of some oriented molecular chain might appear. So the relationship between tensile strength and strain is complex.

From Figure 8 and Figure 9, we know that both the tensile strength and the elongation at break were increased. This is mostly due to the interaction of the disorientation effect of some oriented molecular chain and the disappearing of the stress focus.

3.3 The porosity

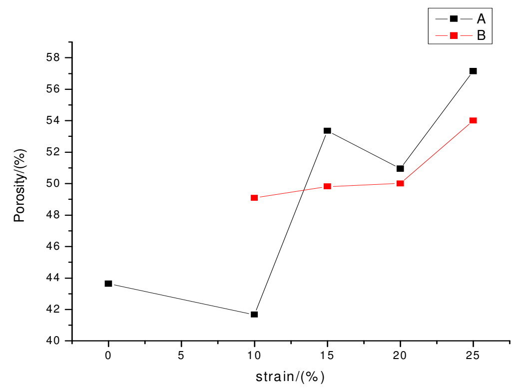


Figure 10. The relationship between porosity and strain in different uniaxial stress state
A---Samples without mechanically softening
B---Samples being mechanically softened

Figure 10 illustrates relationship between porosity and strain in different uniaxial stress state. A ring trend was found in the porosity with increasing the external forces. With increasing the stretching strain, the porosity of the samples mechanically softened decreases more obvious than the corresponding ones, i.e., the ones just stretching. The main reason may that the molecular chain were stretched when the sample was in the stress state, and both the distance of each crosslinking points and the porosity were raised. The internal stretching molecular chains have intertangled after the mechanically softening, resulting a less porosity.

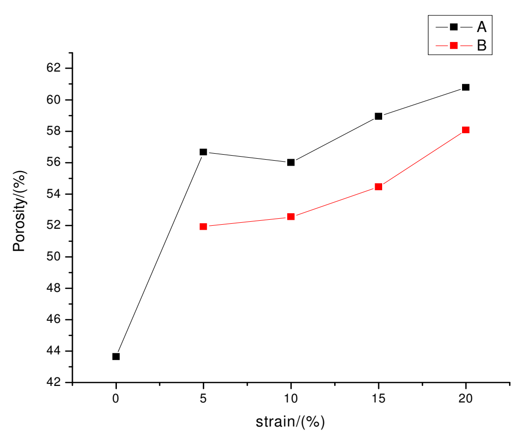


Figure 11. Relation between porosity and strain in different plane stress state
A---Samples without mechanically softening
B---Samples being mechanically softened

Figure 11 shows the relation between porosity and strain of samples in different plane stress state. A rising trend was found in the porosity with increasing the external forces. The porosity of mechanically softened samples decreases more obvious than that of the corresponding controlled ones, i.e., the ones just stretching.

4. Conclusions

Both the uniaxial and the plane stretching can improve the mechanical properties of the samples, yield of the leathers, and the porosity. Mechanically softening may improve the tensile strength and the elongation at break of leathers, while the porosity was decreased.

5. Acknowledgements

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6. References

Attenburrow G E, 1992, The Rheological Study of Leather,JSLTC.

Ciliberto A, Cavaccini G, Salvetti O, et al., 2002, Porosity detection in composite aeronautical structures[J]. Infrared physics & technology, 43(3): 139-143.

C K Liu, Latona N P, Ramos M A, et al., 2010, Mechanical properties and area retention of leather dried with biaxial stretching under vacuum[J], Journal of materials science, 45(7): 1889-1896.

K Y Tang, 2012, The Physical and chemical properties of collagen, Science Press.

Musa A E, Gasmeiseed G A., 2012,Upgrading of rural garad-tanned crust leathers[J], Journal of the Society of Leather Technologists and Chemists, 96(1): 27-31.

Wright D M, Attenburrow G E., 2000, The set and mechanical behaviour of partially processed leather dried under strain[J]. Journal of materials science, 35(6): 1353-1357.