Paper C7

Study on variational regularity of leather creep property under lastometer deformation in different finishing

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Abstract

Leather mechanical property is changed after vibration staking、staking、milling、toggling and finishing during the dry processes, leads to the variation of leather final creep property. Based on systematic experiment and study in each dry process, the variation of leather creep property is characterized by the creeping strain function of leather ε(t) and the creeping delay time τ; the balanced deformation of leather take much time as the value of τ increased, and vice versa. The experimental results show that, the creeping strain function of leather ε (t) under lastometer deformation after each process still conforms to modified Kelvin models; as the increase of intensity, the creeping delay time τ shows different variational trend. The value of τ was respectively increased after vibration staking, staking and milling, the value of τ was respectively decreased after toggling and finishing; So the value of τ of leather has a certain correlation with dimension stability of leather.

Key word: creep; lastometer deformation; leather

Forward

Leather is natural protein polymer material; its creep property is one of the main contents of viscoelasticity. The creep property reflects mechanical performance of leather in the state of long-term load. Leather keep the state of creep during use at most cases, so the usable performance of leather is characterized by the creep behavior. Leather is a material used to make shoes, clothes, car seat covers sofa, bags, belts and so on, so its creep behavior is very important to measure its dimension stability in the load.

The creep property of leather has a close relation to history of load. After leather turn into dry condition, leather final creep property is determined by these dry processes and their strength, such as vibration staking, staking, milling and toggling. In this paper, the creep behavior of leather is systematic studied in each dry process, so as to explore the law of leather final creep property and each dry process, while the variation of leather creep property around finishing is studied. It is summarized that the correlation and variational regularity between leather creep property and each factor of dry process.

The systematic experimental results show that, the creeping strain function of leather ε (t) under lastometer deformation conforms to modified Kelvin models; the significant level of every model is more than 99%. And its mathematical expression is as follows:

$$\varepsilon(t) = \varepsilon_a - \varepsilon_b e^{-t/\tau} \qquad (1)$$

There into: ε(t) as the creeping strain function of leather, t as time variable(s);

$\varepsilon_a=\varepsilon_0+\varepsilon(\infty)$ is constant, ε_0 is the instantaneous strain produced spring model tandem with Kelvin mechanics units;
$\varepsilon_b=\varepsilon(\infty)$ is the balanced strain of Kelvin mechanics units;
τ is the creeping delay time(s) of Kelvin mechanics units.

In this paper, based on the creeping delay time(τ) as the creep property parameter under lastometer deformation, the variation of leather creep property is studied after each dry process.

1 Experimental section

1.1 Materials and equipment

Cattlehide upper leather, sofa leather, furniture leather, Chinese leather factory provide; lastometer testing apparatus, self-make.

1.2 Experimental method

1.2.1 The methods of sampling

Wafer sample cut with 50mm diameter for lastometer experiment, in the circumstance that temperature: (20±2) ℃ and relative humidity: (65±5) %, leather sample is air conditioned at 48h.

1.2.2 Determination and calculation of the creeping delay time (τ)

Leather sample is spread flat in lastometer testing apparatus epidermal area downward, and fixed with clamp. The testing principle picture is seen by Fig 1.

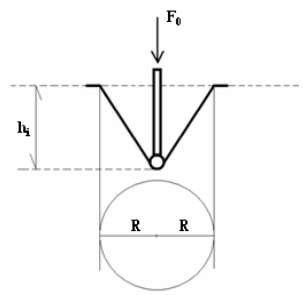

Fig 1 Principle picture of lastometer testing apparatus measuring leather creep

The lastometer pole with loaded force (F_0 = 5.00N) is slowly down. When the pole head touch sample, time begin to record, the first deformational data (h_1) after 5s, then deformational data (h_i) is recorded every 10s until 350s; a series of experimental data about time (t) and lastometer height (h) was received, then transformed into theses data about time (t) and strain (ε) trough the creep strain formula (seen by formula (2)). With formula (1) as mathematical model, the creep testing data under leather lastometer deformation is simulated with nonlinear simulation of Originpro7.5 [2], and the creep delay time (τ) of sample was calculated.

$$\varepsilon = \frac{\sqrt{h^2 + R^2} - R}{R} \qquad (2)$$

1.2.3 Contrast test of Stretched rate (E) and the creep delay time(τ)

10 samples were cut from the standard sampling part of bilateral symmetry along backbone of 8 pieces of cattlehide upper leather. The left samples were used to determine Stretched rate, the right used to determine the creep delay time. The arithmetic mean of each test result was calculated respectively. the creep delay time of 10 samples were given, then relative mistake was calculated, if the relative mistake is less than or equal to 10%, the mean of data is effective; if the relative mistake is higher than 10%, the sample should be increased until meet the requirement of tested result.

2 Result and discussion

2.1 Influence of constant load (F_0) on the creep delay time (τ)

In most cases, the greater the constant load(F_0) is, the easier the balanced creep deformation reach in a short time, the less corresponding creep delay time (τ) is, which is shown clearly from the experimental data of different leather about the creep delay time(τ) under the constant load(F_0) in table 1.

Table 1 The relationship of constant load (F_0) and the creep delay time (τ)

Constant load F_0/N	**the creep delay time** τ/s			
	upper leather	Soft upper leather	Sofa leather	Sheepskin garment leather
1.00	18.3	13.2	9.76	4.65
2.00	17.0	14.6	8.23	3.45
3.00	14.1	11.0	6.65	4.12
4.00	12.3	8.55	6.17	3.71
5.00	8.41	6.43	5.02	3.12
6.00	8.07	5.98	4.45	3.67
7.00	7.82	6.01	4.87	3.54

The data indicated from table1, the change of the creep delay time (τ) reach a plateau as constant load reach 5.00N; as the leather is softer, the variation scope of the creep delay time (τ) is less. Because under enough load, leather fiber become level, and the level state of fiber is keep, lead to the change of the creep delay time (τ) trend to stable. The fiber of soft leather becomes level in minor external load with great speed, so its creep delay time (τ) is relative less.

Therefore, constant load is 5.00N in creep experiment of upper and sofa leather; constant load is 4.00N in creep experiment of sheepskin garment leather; constant load is 7.00N or 10.00N in creep experiment of relative hard and worse extensibility of leather.

2.2 The relationship of Stretched rate (E) and the creep delay time (τ)

According the standard of <upper leather> QB/T1873-2004, Stretched rate (10N/mm^2) should be less than or equal to 35%, which limit the dimension stability. It was listed from the table2, the relationship of Stretched rate (F_0) and the creep delay time (τ)

Table 2 The relationship of Stretched rate **(E) and the creep delay time (τ)**

Sample number	1	2	3	4	5	6	7	8
Stretched rate (E/%)	12.5	15.8	25.1	26.3	30.5	31.8	32.3	33.6
Creep delay time (τ/s)	31.6	26.4	15.4	14.9	13.3	11.5	11.8	10.4

The data showed from table 2, there are certain relevance between Stretched rate (E) and the creep delay time (τ) of upper leather. As the Stretched rate increase, the creep delay time presents downtrend, the dimension stability decreased. Leather with minor Stretched rate has tight fiber structure. Under certain external force, the fiber structure is changed slowly, so the rate of creep strain is also lower, corresponding creep delay time greater, the dimension stability better.

2.3 Variation trend of the creep delay time (τ) of leather after different process

The fiber setting was promoted after toggling. In the contrast test, set the pelt after toggling as control sample, the variation of the creep delay time of pelt was studied after staking (two times of vertical and horizontal respectively), vibration staking(continuous two times) and milling(6h). the experimental results were listed by table 3 and table 4. there into $\triangle\tau = \tau - \tau_0$ represents the increment of the creep delay time around these machining processes, τ and τ_0 represent the creep delay time before and after toggling respectively. The process of toggling is not used in the process of sofa leather in most factories, but the process of toggling was used in this experiment, so as to the contrast.

Table 3 Increment of the creep delay time around the special machining process of cattlehide upper leather

Machining operation	τ_0/s	τ/s	$(\triangle\tau = \tau - \tau_0)$/s	$[(\triangle\tau/\tau_0)\times100]$/%
staking	125.0	38.8	86.2	69.0
vibration staking	118.7	61.9	56.8	47.9
milling	97.5	27.0	70.5	72.3

Table 4 Increment of the creep delay time around the special machining process of cattlehide sofa leather

Machining operation	τ_0/s	τ/s	$(\triangle\tau = \tau - \tau_0)$/s	$[(\triangle\tau/\tau_0)\times100]$/%
staking	91.3	29.1	62.2	68.1
vibration staking	101.4	43.7	57.7	56.9
milling	97.6	14.6	83.0	85.0

These data showed from table3 and table4, the creep delay time of the pelt presents all drastic downtrend after each process of staking, vibration staking and milling. This because the pelt fiber was loosen in process, capacity of sliding between the fibers is greater. When subject to the lastometer load, the balanced time of creep deformation is obviously lower, the dimension stability of pelt decreased. It was indicated from the change rate of increment of the creep delay

time [(□τ/τ_0) ×100]; the loose effect of pelt fibers was the highest after milling, intermediate after staking, and the relative worse after vibration staking. Compared with upper leather, sofa leather demand softer, relative higher protein content of pelt, so the its change rate of increment of the creep delay time[(□τ/τ_0)×100] is higher than upper leather after the same machining process of staking, vibration staking and milling. According to above experimental result, the principle summarized coincides with the experience in practice.

2.4 Influences of the processing intensity on the creep delay time (τ) of pelt

Set the pelt after toggling as the control sample, the vibration of the creep delay time of the pelt in process was studied, through gradually increased the number of times of staking or vibration staking, successive increased the time of milling.

Table 5 The staking intensity effect on the creep delay time of Cattlehide upper leather

Machining operation	τ_0/s	τ/s	(□$\tau = \tau - \tau_0$)/s	[(□τ/τ_0)×100]/%
First staking（one time of vertical and horizontal respectively）	108.7	56.9	51.8	47.7
Second staking（two times of vertical and horizontal respectively）	125.0	38.8	86.2	69.0
Third staking（three times of vertical and horizontal respectively）	114.7	31.4	83.3	72.6

Table 6 The vibration staking intensity effect on the creep delay time of Cattlehide sofa leather

Machining operation	τ_0/s	τ/s	(□$\tau = \tau - \tau_0$)/s	[(□τ/τ_0)×100]/%
First vibration staking	97.7	56.3	41.4	42.4
Second vibration staking	101.4	43.7	57.7	56.9
Third vibration staking	99.1	30.2	68.9	69.5

Table 7 The milling intensity effect on the creep delay time of Cattlehide soft upper leather

Machining operation	τ_0/s	τ/s	(□$\tau = \tau - \tau_0$)/s	[(□τ/τ_0)×100]/%
Milling 2h	91.4	39.3	52.1	57.0
Milling 4h	87.6	25.6	62.0	70.8
Milling 6h	90.9	7.28	83.6	92.0
Milling 8h	86.1	5.66	80.4	93.4

The experimental results indicated from table5, as the times of the staking increased, the pelt fibers was loosen, and its creep delay time gradually lower, the its dimension stability begin to decrease, the creep strain increased. But the creep delay time of the pelt reached 31.4s when

staked three times, which could not reach the standard required of the finished upper leather (the standard of the creep delay time of finished upper leather is about from 7s to 11s). It was found that the loose grain of the pelt is easier produced as the number of times of the staking increased.

The experimental results indicated from table6, the pelt fibers was mild loosen after the vibration staking. The damage of pelt fibers is relative lower; the creep delay time of pelt decrease content was relative lower after the vibration staking. The creep delay time of the sofa leather only reached 3.02s when milled three times, so it could not reach the standard required of the finished sofa leather when the vibration staked (the standard of the creep delay time of finished sofa leather is about from 3s to 6s).

The experimental results showed from table7, the pelt fibers was obviously loosen after the milling. The creep delay time of pelt decrease content was the greatest after the milling. The creep delay time of the soft upper leather reached 7.28s when milled 6h.

2.5 Influences of the process of the finishing on the creep delay time (τ) on leather

During the finishing of pelt, some the finishing agent would penetrate the inner of pelt, and combined with pelt fabrics. The influences of the process of the finishing on the creep delay time (τ) on leather is complicated, because the elastic module and elastic strain of the finishing agent are often higher than the pelt, some factors of the finishing agent, such as its type, its cohesion to pelt fabrics .etc., is quite complicated. According to a series of experimental data listed of the creep delay time from the table 8, the creep property of leather is preliminary learned during the process of finishing, set cattlehide sofa leather for a research object, the finishing to finished leather for research process.

Table 8 Variation of the creep delay time of cattlehide embossed upper leather during the finishing

Dry process	Control sample and τ_0/s	τ/s	(□τ = τ - τ_0)/s	[(□τ/τ_0)×100]/%
vibration staking	Pelt after the toggling, 113.2	57.7	55.5	49.0
finishing	pelt after the vibration staking, 60.2	68.9	-8.7	-14.5
embossing	leather after the vibration staking, 66.7	98.1	-31.4	-47.1
milling	Leather after the embossing, 93.5	10.8	82.7	88.5

It is shown from Table8 that, the creep strain is marked by the creep delay time of leather in each dry process of finishing and embossing. The creep strain of leather is less and the value of τ increased, which is beneficial for improving the dimension stability of leather. The finishing material with better elastic module made primary contribution for the creep strain of leather, because the creep strain of leather is less after the finishing. The creep strain of leather is less by a wide margin, because the heating setting of leather fabrics is given after the embossing. But the creep strain property of the finished leather is not affected after the process of the finishing and embossing, and the creep property would meet the requirement of the finished leather through control the later machining process, such as milling, staking and so on.

3 Conclusions

The variation of creep property of leather is given by the creep delay time (τ) in the theory in main machining process during the finishing, and the dimension stability of using leather was studied by parameter. Dimension stability of leather has better performance as the value of τ increased. The creep delay time (τ) of leather has a certain correlation with stretched rate (E).

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