



The influence of first time drying on the characteristics and performance of leathers

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In leather making, the influence of strain within first time drying is very significant. The effects are readily observed in practice, but the rationale is less easy to define. This article presents findings from a series of structured investigations into factors that are involved in drying, and how these relate to leather behaviour and characteristics.

As an overview, this article is short on detail, but the conditions of testing and statements made in each section are presented in detail in the original papers. Each section draws from these papers, and references are given accordingly.

In the earlier investigations^(1,2,3,4) trials were performed by applying strain one direction (*uniaxial*) to strips of leathers. In the final studies⁽⁵⁾ this changed so that strain could be applied and measured simultaneously in two directions. As retanning, filling and softening agents strongly affect the fundamental characteristics of a tannage, all of the investigations were based on wet blue leather samples.

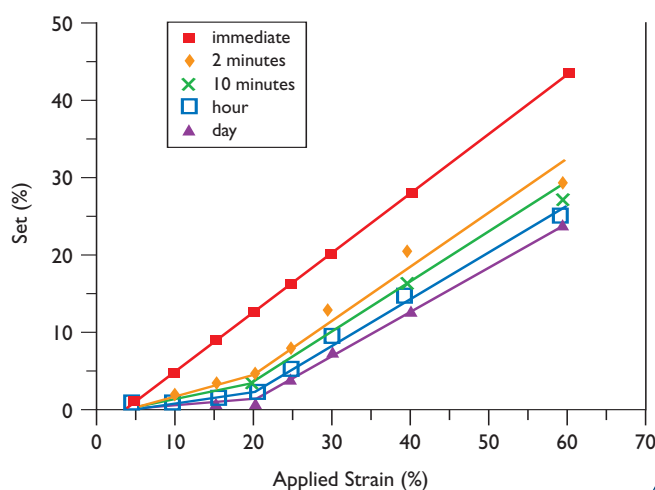
The dependence of set on the degree of strain⁽¹⁾

Samples of lightly sammyed wet blue leathers were strained up to 60% and held for 10 minutes. On the release of tension the level of extension that remained—expressed as percentage set—was measured at different time periods. The findings are shown in *Panel 1*.

This shows that for wet leathers:

- any gains in set are rapidly lost over a short period of time
- very little long-term set remained at strains less than 20%

Panel 1: Set plotted against degree of applied strain. Wet blue leather strained parallel to the backbone.



Definitions

In Materials Science the following terms are used when stretching experiments are being discussed:

- **Strain:** This is the increase in length per unit length and is expressed as a percentage.
- **Stress:** This is the load per unit cross sectional area through which a load acts. The preferred unit is the MegaPascal.
- **Set:** In this article set is defined as the residual increase in length, after a material has been stretched and released, divided by the initial length of the material. As with strain it is expressed as a percentage.

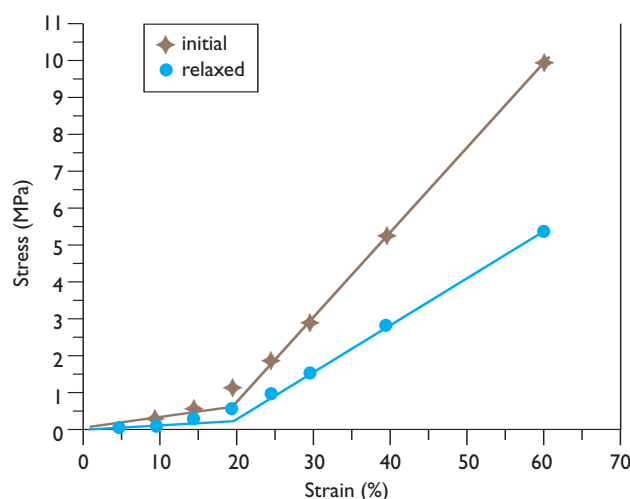
Stretch is a general term used when a material is extended. It does not specify extension in terms of uniformity, percentage or direction.

The dependence of strain upon stress⁽¹⁾

The rise in stress required to increase strain by a given amount in these leathers shows a change at 20% strain. Below this value the stress increase was relatively small and proportional to the percentage strain. To achieve strain greater than 20% the rate of loading showed a significant increase. A linear relationship continued between stress and strain, but it is clear that a transition occurred at 20% strain, and this is shown in *Panel 2*.

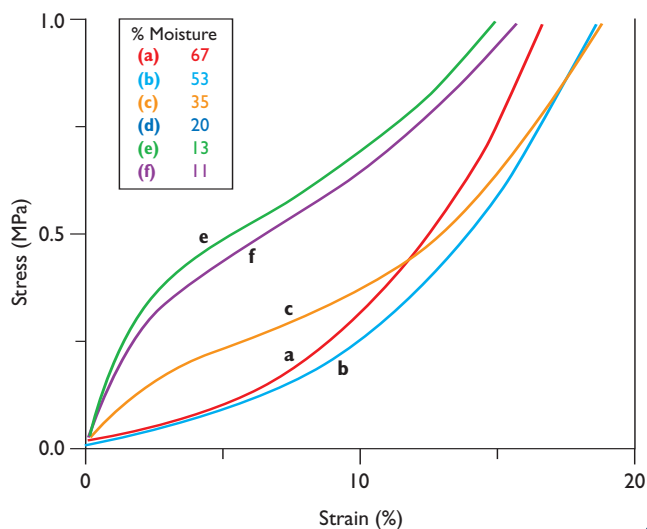
Why does this transition occur? Where the strain is less than 20% it appears that there is movement of the collagen fibres relative to each other but with little actual stretching of these ➤

Panel 2: Initial strain curve for wet blue leather strained parallel to the backbone.





Panel 3: Stress-strain curves for partially processed leather at different moisture contents. Samples tested parallel to the backbone.



fibres. At higher values of strain the collagen fibres are being directly stretched, and this gives rise to a greater stress. Stretching of the fibres is associated with the greater/more long lasting set occurring above 20% applied strain.

The role of moisture in the relationship between stress and strain⁽¹⁾

The percentage of strain relating to a given stress was recorded at different moisture contents. At moisture contents above 53%, a relatively low load initially produces a considerable degree of strain; however, high loadings were then required to gain higher levels of strain.

When the moisture content was less than 35% a greater rate of stress increase was required to first stretch the leather, followed by a low increase of stress with strain. A further increase in stress levels was then required to achieve higher values of strain. These results are given in *Panel 3* where the behaviour at high moisture content produce a simple "J" shaped curve, but at lower moisture contents this changes to an "S" shape.

The role of moisture in the degree of set⁽¹⁾

A strain of 20% was applied to the samples, and the percentage of set recorded after one hour. A relatively high level of set was retained in leathers with lower moisture contents, whereas the set retention at the higher moisture levels was very low. This is shown in *Panel 4*.

There was no fibre lubrication at low moisture contents, so the contraction was limited.

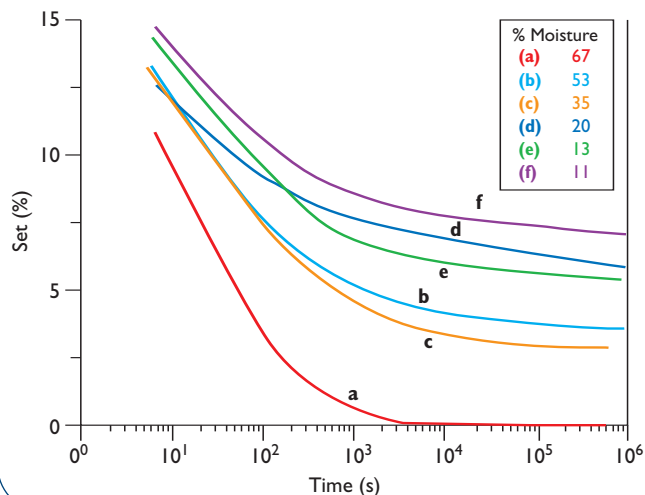
The role of time in the determining the degree of set⁽¹⁾

A sample with moisture content of 20% held at 20% strain for 10 seconds retained 49% of this strain. When the holding time was increased to 10 minutes, 60% of the strain was retained. This shows that the length of time that a sample is held under strain is critical for the retention of set.

The retention of set^(1 and 2)

If wet leathers are strained to a given value, then dried under this strain, a high level of set is retained. Under these conditions, wet leathers strained to 20% retained a set of 19%. Even when

Panel 4: Set plotted against time after release, sample tested parallel to the backbone.

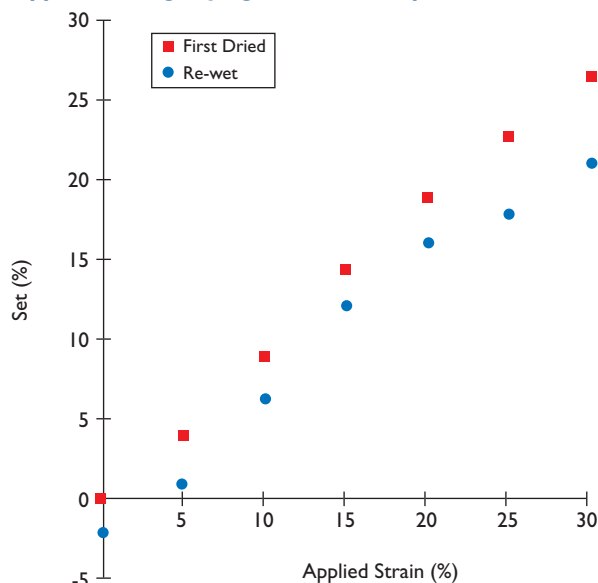


these samples were wet back, then re-dried under tension free conditions, a set of 16% remained. In comparison, wet leathers that were similarly strained, then dried under tension free conditions, lost all of this strain.

In another series of investigations, strips of wet blue were taken from the standard sampling position of a hide parallel to the backbone, saturated with water, blotted, and then strained to various values. These were then allowed to dry under strain in a room at 20°C and 65% Relative Humidity. When the leathers had dried and stabilised at 25% moisture, the samples were released.

One day later the percentage set was measured. This showed that the value of set retained is almost in direct proportion to the percentage strain applied to the wet sample. Moreover, when these samples were fully rewetted, then allowed to dry tension-free, a considerable amount of the initial set was retained. This is shown in *Panel 5*.

Panel 5: Heading: Set plotted against the strain applied during drying of leather strips.



Squares represent set measured after first time drying (hide 1). Circles represent set measured after re-wetting then drying again. In this second drying samples were not constrained.



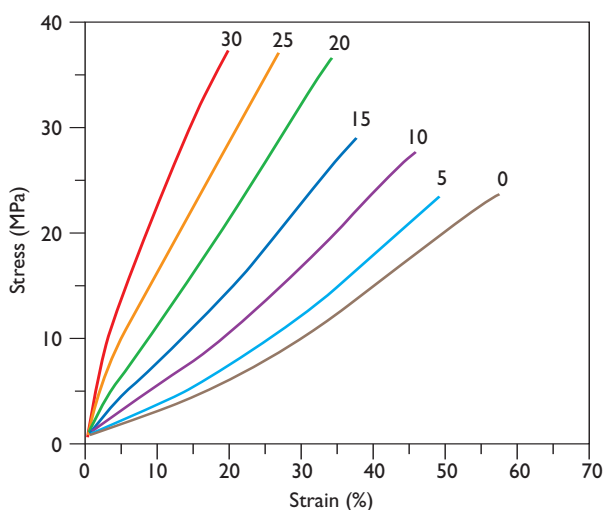
Characteristics developed during drying in relation to applied strain and set⁽²⁾

Wet blue samples taken perpendicular to the backbone were similarly dried when strained to various values. When dry these leathers were subjected to tensile testing using an Instron 1122 machine. This showed that as the percentage strain applied to the leathers before drying increased:

- The stiffness of the leather increased
- The strain tolerated before leather broke decreased
- The stress required to break the leather increased

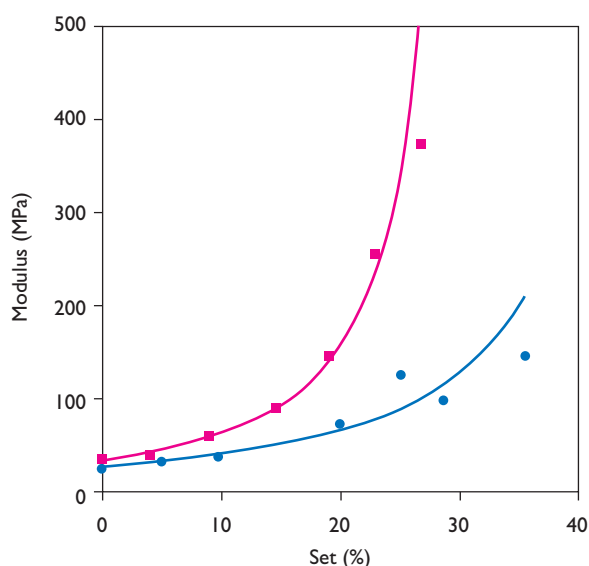
This is illustrated in *Panel 6*.

Panel 6: Stress-strain curves from tensile testing of leather strips dried under an applied strain (%).



Stress-strain curves from tensile tests of leather strips (from hide 1) dried under an applied strain (%). The value of applied strain applicable to each curve is indicated.

Panel 7: The tensile modulus of leather strips dried under strain plotted against their set.



Squares represent data from hide 1, circles data from hide 2.

The stiffness of these dried samples was characterised by measuring the slope of the curves at 2% strain. This produces a value that relates to stiffness (*modulus*), which can then be plotted against the percentage set as given in *Panel 7*.

This shows that the increase in firmness at values greater than 10% set is considerable. Over the range 0 to 30% set, the increase in firmness for the first hide (*samples parallel to the backbone*) is over ten-fold. However, for leather from the second hide (*samples perpendicular to the backbone*) the increase is approximately four-fold.

The behaviour of collagen fibres during drying^(1,2,3 and 4)

The findings have shown that there is no single relationship between the strain applied to a given leather and the resulting percentage set. The relationship changes according to the initial moisture content of the sample, and the time that the sample is held under tension.

When leather is strained, then dried under tension, it acquires a high degree of set. Although some of this set is lost when the sample is re-wetted, a considerable amount remains. This behaviour can be compared to that of water saturated leathers that are similarly strained but not dried. On release of tension the leather returns to its original configuration with no retention of set.

Other physical properties of a leather change during drying. As the applied strain is increased, so the dry leather becomes harder and retains less ability to stretch before breaking.

It appears that as leathers are strained, initially there is movement of the collagen fibres in relation to each other as they align, but this can happen without much actual stretching of the fibres. If the percentage strain is increased the collagen fibres are directly stretched, and this requires considerably more stress.

By passing an X-ray beam through leather and looking at the way the beam is scattered it is possible to detect the degree to which fibres are aligned along a given direction. This approach has been used to show how fibres align as strain is increased⁽³⁾.

It has been speculated that, as moisture is lost from these wet strained leathers, the taut collagen fibres and constituent fibrils adhere to each other. The drying allows new contacts between collagen molecules, which were not present when the leather was fully wet: these contacts may allow crosslinking reactions to result from the closeness of amino acid residues.

When dry such linkages hold the strained fibre network in the new deformed shape. These inter and intra fibre connections are sufficiently stable to largely survive during rewetting of the dried leathers. So the level of set remains surprisingly high through rewetting and drying cycles.

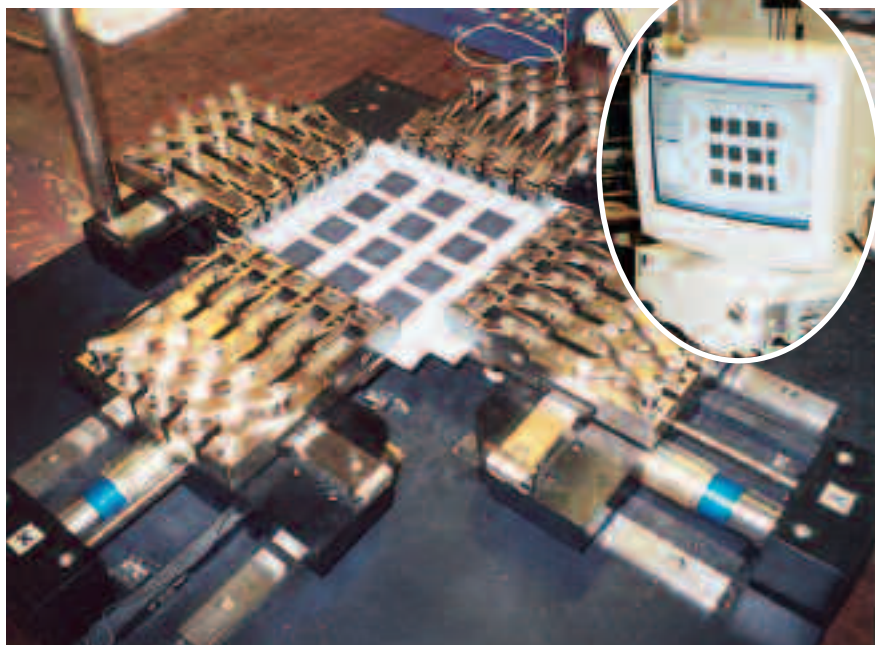
The effects of the biaxial stretching of leather⁽⁵⁾

The findings from earlier investigations were based on observation of uniaxial deformation of leather, that is the leathers were stretched in a single direction. Further investigations have taken place where leathers were stretched biaxially, that is in two directions. In these investigations the sample was clamped in the specially made testing machine, then simultaneously stretched in two directions at right angles until a required level of strain was attained. The testing machine is shown in *Panel 8*.

As with earlier investigations^(1,2,3,4), the wet leathers were stretched to different levels of strain (*but this time biaxial strain*), then allowed to dry under strain prior to release. In this series of trials the samples were subjected to tensile testing to break, but with the direction of sample changing from parallel to the ►



Panel 8: The biaxial testing apparatus.



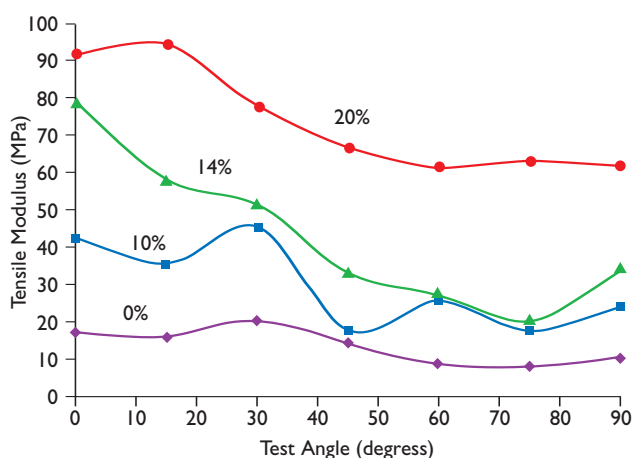
The biaxial testing apparatus can be used in conjunction with computer analysis to investigate the deformation of leathers stressed under different conditions.

backbone (0°), to perpendicular (90°) in increments of 15° .

The results confirmed the earlier uniaxial findings, in that the higher the strain during drying, the greater the firmness of the dry leather.

They also showed that the stiffness of the leather changes according to the direction of the test. The leather is slightly stiffer at low angles to the backbone line when dried stress free, and these changes in physical properties in relation to the direction of test are largely maintained as drying strain is increased. This can be seen in Panel 9. This anisotropy (*the direction of the test*

Panel 9: Tensile stiffness at different test angle for leathers dried under different levels of biaxial strain.



A plot of tensile modulus against test angle for leather dried under equal biaxial strains of 10, 14, and 20% as indicated. Also shown are results for a control sample dried without constraint (0%). Angles are measured with respect to the Y-axis.

affecting the result) is a reflection of a preferential fibre run approximately parallel to the backbone.

It is clear that biaxial stretching markedly affects stiffness. If the average values are taken, then a biaxial strain of 10% increases stiffness of the sample by 114%, a 14% strain by 209%, and a 20% strain by 422%.

A comparison of X-ray diffraction patterns obtained with the beam aimed through the leather surface and through the leather cross section shows that the main effect of biaxial stretching is to cause the average angle between fibre and surface to reduce⁽⁵⁾. It is believed that the increase in stiffness of leathers dried under biaxial strain is largely due to this type of re-orientation of the collagen fibres.

Overview of findings

In leather making practice, it is known that the conditions of drying strongly affect the characteristics and properties of the final leather. These studies have taken place on wet blue leathers whose characteristics remain unmodified by products designed to refine the basic properties of tannage.

The outcome from these investigations is closely in-line with observations made in practice. The value is that as different conditions that relate to drying have been applied, the major changes in physical properties have been quantified. It has also demonstrated that gains in one facet are balanced by other changes. Permanent gains in area are offset by an increase in hardness in the dry leather, and a lower tolerance to extension.

The studies draw attention to the rapid loss of area from wet strained leathers when they are allowed to relax. They also apply a rationale to the changes occurring at a basic level as moisture is removed from leathers held under strain. It is clear that a re-alignment of fibres occurs when leather is stretched biaxially resulting in a reduced angle between fibres and the surface. However, the strength and permanence of the cross-linking that appears to take place within and between these stressed fibres is demonstrated by the high levels of set that are possible under these conditions. ⚙️

References:

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