



Cross-hide variations in physical properties:

The determination of the relative degree of stretching in different directions

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Natural variability in the skin

There are considerable variations in the degree of resistance to stretch across the hide of a living animal. The areas of butt, backbone and across the rib cage do not need to stretch to the same degree as the belly, shanks and axilla parts. In addition, there are variations in the degree of stretch resistance in directions parallel and perpendicular to the backbone.

This variability is due to the non-uniform layout of collagen fibres within the skin which are aligned to differing degrees in different locations. Thus the starting material for leather manufacture is highly non-uniform. Subsequent manufacturing steps used to make leather will significantly modify this naturally occurring non-uniformity.

Round hides into flat usable leather

One of the major steps in leather manufacture is the conversion of rounded hides and skins into flat usable leather. Many of the steps in the wet stages of leather making—liming, deliming and bating and mechanical processes such as fleshing, splitting, and mechanical action in drumming—are accepted as contributing to this flattening, and certainly influence the physical properties of leathers.

However, it is mainly in the first-time drying process that a permanent shift from the natural rounded form to a mainly flat shape occurs. Within, say, toggle drying, the wet leathers can be stretched relatively easily to a flattened form and when the leather is in the final dried state, this deformation is largely retained. The greater the strain retained throughout the drying cycle the more

complete is this deformation to the flat form, and this can be reinforced by using higher temperatures in drying when the free water has evaporated and the leather enters 2nd-phase drying.

This change from a 3-dimensional hide to 2-dimensional leather is considerable, and has been likened to taking a globe of the earth, and flattening it into the form of a map, where the deformation of longitudinal lines, oceans, and land masses is apparent. The highly contoured legs and shanks, which in particular need flattening, can be seen in *Panel 1* where these parts of a salted hide have been partially opened out.

Changes in properties due to deformation in leather manufacture

As a generality, it has been observed that the lines of fibre orientation (fibre run), least stretch and the direction of the hair follicles across a hide lie in the same direction, with the lines of greatest stretch found at right angles to this direction. But this relationship may change as a result of the leather production process. The easily stretched areas of the belly and shanks have to become more similar in performance to the other major hide parts for the leather to have value as a material for construction purposes. In vacuum drying leather may be deformed unevenly as it is spread out and toggle drying may stretch the leather more in one direction than another. Following such changes, when leather components are brought together in construction and end-use, whilst the performance is reasonably predictable it is highly desirable, for optimum utilisation, that more information is available concerning the variability of leather stretch behaviour.

Panel 1 The highly contoured legs and shanks of a raw hide

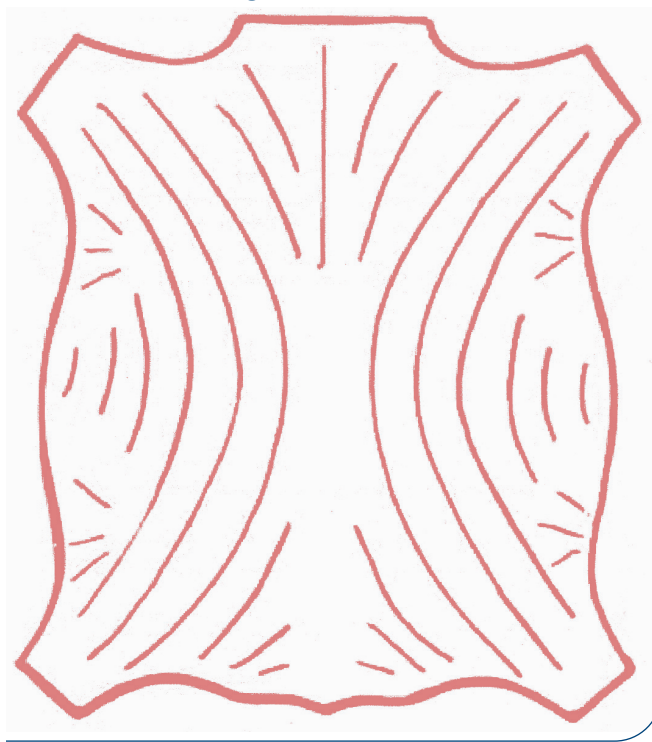




Cross-hide variations in the ratio of parallel and perpendicular degree of stretching under a given load

The variability discussed above is especially noticeable in terms of the differences between resistance to parallel and perpendicular strain (relative to the backbone line). Such behaviour would be seen as a disadvantage with most materials used in manufacture, but it is used to good advantage, especially within footwear construction. Relative ease of deformation is needed for shaping footwear parts (lasting), and for comfort in fit and wear. Also the shoe must retain its shape in the toe to heel direction, so that any deformation best occurs at right angles to this line. Components can be cut from a hide to favour this “toe to heel line”, and the generalised direction of these lines in a hide or skin—known as lines of tightness—is illustrated as *Panel 2*. However, because of the deformation caused within leather manufacture, a particular leather may have a line of tightness pattern which is significantly different from the generic one shown.

Panel 2 The lines of tightness

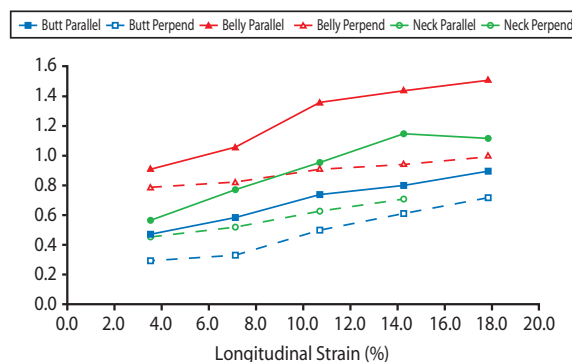


To investigate how lines of tightness may be characterised the ratio of longitudinal to lateral stretch variation across a hide was measured. Rectangular test strips of 220 x 25 cm were taken from a chrome tanned hide that had been retanned/fatliquored and processed to the crust condition. These strips were cut both parallel and perpendicular to the backbone, and were sampled from the butt, belly and shoulder areas. These samples were then stretched and an imaging system used to simultaneously measure both the longitudinal strain (relative extension) and lateral strain (relative contraction). This difference between longitudinal strain (ϵ_1) and the relative lateral contraction (ϵ_2), is known as Poisson's Ratio, and is expressed as ϵ_2/ϵ_1 .

These leather strips were strained longitudinally between 3.5% and 18%, and the findings from the butt, shoulder and belly parts are shown in *Panel 3*:

Panel 3 Variations in the ratio of longitudinal strain to lateral strain:

- 1) Samples cut from butt, shoulder and belly regions
- 2) Test strips parallel and perpendicular to the backbone



The lowest values for Poisson's Ratio are found in the butt with samples taken perpendicular to the backbone:

- At 3.75% longitudinal strain, the ratio was 0.30 (*lateral contraction 1.1% [3.75 x 0.3]*)
- At 18% longitudinal strain, the ratio increased to 0.70 (*lateral contraction 12.6% [18 x 0.7]*)

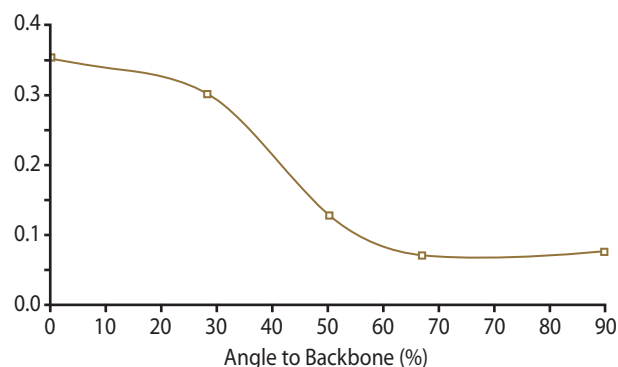
The largest values for these ratios are found in the belly parts with samples taken parallel to the backbone:

- At 3.75% longitudinal strain, the ratio was 0.9 (*lateral contraction 3.4% [3.75 x 0.9]*) - that is three times larger than the butt sample
- At 18% longitudinal strain, the ratio was 1.5 (*lateral contraction 27% [18 x 1.5]*) - that is slightly more than twice that of the butt sample.

For all hide parts sampled, stretching parallel to the backbone gave a higher Poisson's Ratio (greatest lateral loss at a given longitudinal strain) than samples stretched perpendicular (lowest lateral loss at a given longitudinal strain).

It is clear that this ratio varies with the angle with respect to the backbone, and this is illustrated in *Panel 4*:

Panel 4 Variations in the ratio of longitudinal strain to lateral strain: Effect of angle to backbone





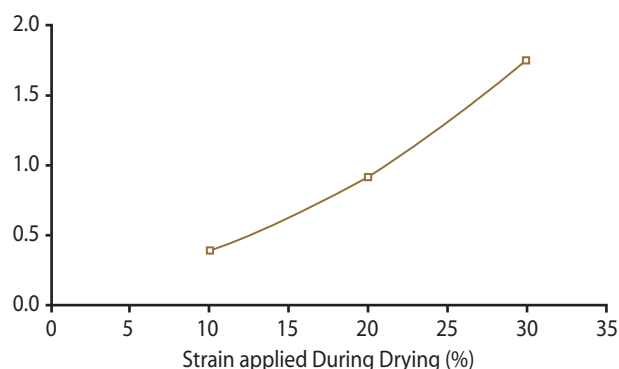
The manipulation of cross-hide variations

These changes in Poisson's Ratio indicate the variations in cross-hide properties according to location and direction. However, the tanner can manipulate these differences by applying different amounts of strain during first-time drying.

This was investigated by stretching wet samples of leather from 10% to 30% in one direction, then allowing it to dry while held in this stretched state. Samples were cut from these dried samples and a longitudinal strain applied in a similar manner to examples given in *Panels 3 and 4*. The findings are shown as *Panel 5* where an increase in strain from 10% to 30% during the first-time drying of leathers caused a permanent shift in Poisson's ratio from 0.4 to 1.8.

Panel 5 Variations in longitudinal strain and lateral contraction:

Samples stretched from 10% to 30% and dried in stretched state



Implications from the investigation

- These findings show that when any leather component is stretched in one direction, then there is a lateral contraction to this axis. This dimensional change is not constant and the values vary across the hide.
- In general, samples or components stretched in the direction parallel to the backbone will show greater relative lateral

contraction than samples stretched perpendicular to the backbone. In addition, components cut from the belly parts will show relative lateral contractions that are far greater in proportion at the same level of strain than components cut from butt or shoulder parts.

- Fibres tend to be orientated along the "lines of tightness" which in many regions lie approximately parallel to the backbone. It appears that higher Poisson's Ratio values are associated with stretching along these lines of fibre alignment.
- Changing the conditions within first-time drying can significantly alter leather properties. If high strain is applied and maintained, then it is possible to change the direction and intensity of fibre alignment. When directional strain is applied to shanks and bellies for extension within first-time drying, and if this strain is greater than applied to the other hide parts, then the distribution of cross-hide Poisson's Ratio can be modified. The "lines of tightness" can thus be modified, and so the relationship between longitudinal strain and lateral contractions within cut components.

Acknowledgements

This paper is based on the paper entitled "The application of image analysis to determine the physical properties of leather", S Kabeer¹, G E Attenburrow², P Picton³, M Wilson³ [(¹) Leather Research Centre, Pakistan Council of Scientific and Industrial Research (PCSIR), D-102, S.I.T.E, Karachi, Pakistan. (²) British School of Leather Technology, University of Northampton, Park Campus, Boughton Green Rd, Northampton, UK (³) Division of Engineering, University of Northampton, Avenue Campus, St George's Avenue, Northampton, UK] by consent of The American Leather Chemists Association.

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Additional information

Mechanical Testing: The test samples were extended on a 5KN Dartec hydraulically actuated mechanical testing machine at a rate of 10 mm m⁻¹. Strain was measured using image analysis as described below.

Image Collection and Analysis: An imaging system was used to simultaneously measure both longitudinal and lateral strain whilst the strip of leather was being stretched. A CV A50 CCD camera with a 12 mm focal length lens was used to capture images. The digital images were transferred to a PC and analysed using a software system called LABVIEW (National Instruments Inc) exploiting the software element called IMAQ Vision Builder. A sequence of images showing the translation of ink spots marked on the leather surface was analysed to give longitudinal strain (e_1) and lateral strain (e_2).

Poisson's Ratio: Most materials have a Poisson's Ratio in the range of 0.3 - 0.5, and a value of 0.5 is seen as the theoretical upper limit occurring in an "incompressible" material such as rubber. It is clear that leather has a Poisson's Ratio greater than 0.5, and it appears that this is because leather is porous rather than a solid material, and that its constituent fibres can move closer together laterally when stretched longitudinally.

Implications: Leather is a natural material and although its mechanical properties are understood in general by users its behaviour is not entirely predictable. A detailed characterisation of the topographical variation of any piece of leather could be of value, and it should be possible to measure this by measuring the ratio of longitudinal to lateral ratio using camera and image analysis.

Related publication: The scientific and commercial significance of variations in strength and stretch in leather. R.Daniels, *World Leather*, November 2007,