Review

The anatomy of leather

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Leather is prepared from vertebrate skin by the chemical stabilization of the fibrous protein collagen, the main solid constituent of skin. The natural three-dimensional fibrous weave of the collagen fibrils is retained intact in the leather, and this paper describes in detail the relation between the fibrous weave as seen under the light and scanning electron microscopes and the physical properties of the leather.

In the main, skins of cattle, sheep and goats are used. These differ in total thickness, fibre bundle size and weave pattern, but offer a variety of raw material from which the tanner can select the skin type best suited for a particular end use. The tanning process can also modify the natural weave in order to achieve the required physical properties. For example the processing can allow fine spaces to remain between the fibrils, so that they are free to move over each other within the fibre bundle. Such a bundle will be highly flexible as will be the leather as a whole. Conversely, if fibrils adhere to each other and are not free to move the leather will be firm. Such fine spaces can be recognized under the microscope as longitudinal striations.

Another important feature which is influenced by the tanning process is the angle at which the fibres interweave in relation to the grain surface. A low angle of weave is required for high tensile strength as this allows the pull to be transferred along the fibre axis. A low angle of weave also allows more frequent interweaving of the fibres within a given thickness of leather, than if the angle is high. As frequent interweaving of the fibres is a prerequisite for strength the tear strength of leather is highly dependent on the angle of weave. This is particularly so in certain types of leather prepared from cattle skin, which is cut into layers to obtain the required leather thickness.

For leather to accommodate stretching, such as that occurring when lasting shoe uppers, or compression and creasing, the individual fibrils need to be free to move within the bundle, and the bundle within the weave as a whole. The changes in the fibre structure that occur under such conditions can be followed microscopically and are described in detail in this paper.

1. Mammalian skin characteristics and the structure of leather*

Although any vertebrate skin can be converted into leather the most commonly used skins are those of cattle, sheep, goats and to a lesser extent pigs. These have a similar basic skin structure consisting of innumerable bundles of collagen fibrils interweaving in a three-dimensional manner. The characteristic layers of tanned cattle skin are seen in the cross-section in Fig. 1. The collagen molecules are extremely long, in relation to their cross-section, (the triple helix being 280 nm long, and 1.4 nm wide) and are naturally orientated during their formation into fibres and bundles of fibres as shown in Fig. 2. These bundles vary in dimension at different

*The terms used in this paper are those in common use in the leather industry but differ in some instances from the terms used by the histologist, and so the following definitions are given:

The fibrous portion of the skin below the epidermis is termed the dermis. The region of the dermis in which the hairs are found is termed the grain layer (marked A in figures). The region of the dermis below the hair roots is termed the corium, and the limiting layer of the skin, where the collagen fibres run in a horizontal manner to form a boundary to the skin where it is adjacent to the muscle of the animal, is termed the flesh layer.
levels within the skin. The largest are to be found in the central region of the dermis or corium, marked B in Fig. 1. In cattle skin these large corium bundles are about 0.1 mm in diameter but these subdivide and become finer (~0.001 mm) as they approach the skin surface.

Towards the flesh surface, which in life was adjacent to the muscles of the animal, the fibres tend to run in a horizontal plane to form a limiting or flesh layer, C in Fig. 1. Towards the outer or grain surface the fibre weave has to accommodate other structures such as hairs, which are found in one distinct layer, the grain layer. This layer, marked A in Fig. 1, extends from the hair roots to the outer surface, which in the untreated skin is composed of the epidermis. The collagen fibres become increasingly fine as they pass through the grain layer, so fine as to be more readily studied by the scanning electron microscope. Fig. 3 shows fibres towards the grain surface 0.001 mm in diameter. At the extreme outer surface of the dermis the fine fibres are only resolved under the light microscope if specifically stained. In Fig. 4 the dermal surface fibres are stained black by silver and are seen lying immediately below the epidermis in the raw skin. The epidermis, together with the hairs, is removed chemically during the early stages of leather processing, and it is then that these fine fibres form the outer surface of the leather. It is the compact interweaving of these fibres which creates the smooth aesthetically pleasing surface of the leather.

The natural weave of the collagen bundles not only varies through the thickness of the leather,