



Solar-reflective (Cool) leather

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Although leather is a product with very unique properties, modern lifestyles continuously demand new products and improved performance features. One of the focal points is the easy care behaviour as well as the comfort of products in daily use—especially those which are in direct contact with the body. Therefore, in leather technology, much time has been invested in improving properties such as water and flame proofing, anti-soiling, dry cleaning and abrasion resistance, to mention just a few. Certain performance attributes can often only be achieved by compromising on the comfort of the leather as this is mainly influenced by surface texture, water vapour permeability, and water (sweat) absorption on the surface.

Another parameter which influences comfort is temperature. It is well known that the temperature of darker surfaces can rise significantly when exposed to sun—just think about steering wheels, dark car seats and black leather garments such as those worn on motorbikes. A new technology for leather has been developed which reduces the build up of solar heat, which can provide the level of comfort consumers expect from a natural product such as leather.

Physical background of solar-reflective leather

To better understand the principle of solar-reflective leather technology let's consider some of the basics. The solar spectrum ranges from the invisible shortwave UV light through the visible (VIS) to near infrared (NIR) and then thermal or far infrared, as shown in *Panel 1*.

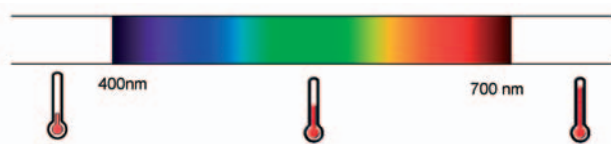
If solar light (energy) is absorbed by ordinary materials or surfaces it is converted into heat energy. The longer IR waves produced by sunlight produce more heat energy when absorbed by a black body than the shorter wavelengths in the VIS or UV range. This is also illustrated in *Panel 2* where the solar (heat) energy distribution is shown over the range of the solar spectrum.

A completely black object, as a poor reflector, will absorb all of the incident radiation from the sun and will in turn emit as much of the radiation as is possible at its given temperature. It follows the rule that surfaces which are good absorbers are also good radiators of a certain wavelength. It does not follow, however, that surfaces which are good absorbers of one wavelength will also be good absorbers of all wavelengths.

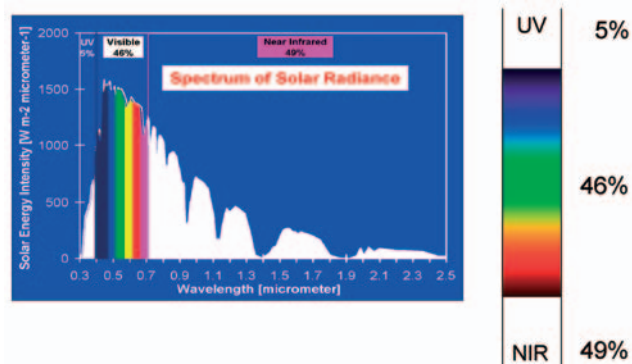
The temperature that a surface will adapt to under sun exposure not only depends on the colour of the body but also on its structure and the type of material. The latter greatly determines to which extent any collected heat is emitted in the far or thermal infrared. For example, a dark grey roof tile made of metal will assume a different temperature than a tile made of clay in the same colour.

In order to design 'cool' surfaces we need high reflection both in the VIS and NIR area as well as good emittance of the waves.

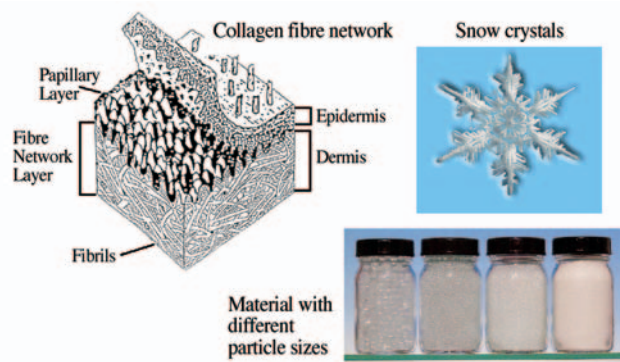
Panel 1: Spectrum of solar radiation and associated temperatures



Panel 2: Solar energy distribution



Panel 3: Solar reflectance and emittance depends on structure and colour of a material



Design of Cool leather

In order to design cool surfaces leather plays a very unique role. Thanks to its structure—which is made up of a fibrous collagen network—it possesses very good solar reflective properties. In contrast materials which are more compact in structure have lower solar reflectance and emit less heat. This is illustrated in *Panel 3* where particles with different diameters and compactness are shown. Powder snow with its crystal structure will remain



cold longer and thus maintain a better shape as a result of its excellent solar reflectance and high emittance of heat. Uncoated natural leather shows excellent thermal comfort, first because of its good solar reflectance properties and second because it is water vapour permeable and can absorb sweat easily.

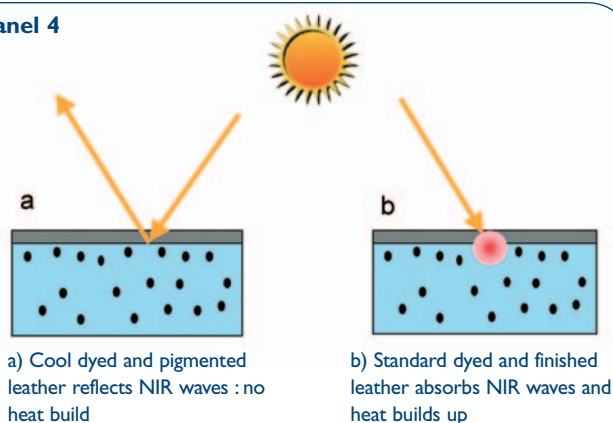
However, things can change if a pigmented finish coat is applied to the crust leather. The pigments in the finish may absorb most of the NIR waves and heat can build up and be dissipated within the finish coat and material. As most of the leathers in daily use have some kind of finish coat this can create discomfort, especially with dark coloured leathers exposed to sunlight. This is not only because of a simple temperature difference, but also because of the more pronounced sweating associated with higher temperatures.

In order to solve this problem it is necessary to develop a leather which has a good NIR reflection and good emittance.

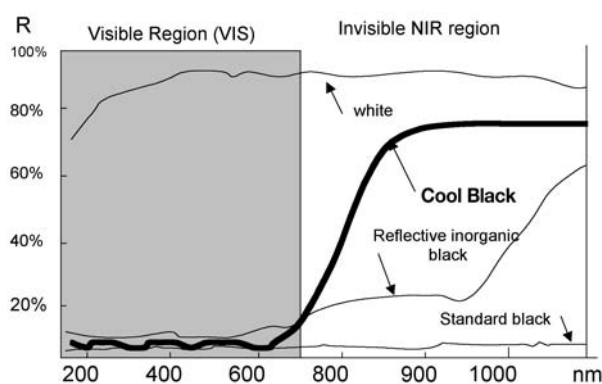
TFL's new patented Cool technology for leather considers crust leather and the finish coat as a whole system in which Cool NIR transparent pigments¹ and Cool dyes² are employed. The new Cool pigments are special, mainly organic, pigments which do not absorb NIR waves but let them pass through the finish coat. The collagen fibre network underneath the finish coat with its good solar reflective properties will then reflect the NIR waves back through the finish coat. No absorption—and thus no heat build up—can take place in the NIR transparent finish coat. In standard finished black leather all of the visible (VIS) and near infrared NIR waves are absorbed by the pigments and transformed into heat which dissipates in the finish coat as illustrated in *Panel 4*.

Another way to obtain solar-reflective leather is through the

Panel 4



Panel 5: Reflective properties of leather finished with different pigments



use of special inorganic pigments (i.e. chromium green hematite for black) which reflect NIR waves. But these inorganic pigments do not reach the solar-reflective figures obtained by the new system using Cool NIR transparent pigments and Cool dyed crust as indicated in *Panel 5*.

Finishing coats made with these 'heavier' inorganic pigments do not exhibit the same natural elegance as the new Cool organic pigments, although they are more stable to UV light exposure. The light and UV stability of the Cool organic pigments is considered to be very good, but the addition of an appropriate light stabilising agent may be necessary to pass the most stringent weathering and heating tests used for automotive leather.

Although the pigments in the finish coat play a significant role in obtaining a good 'cool' effect, the dyes used for colouring the crust also have an influence on solar reflection. They must also show good NIR reflection and only the combination of Cool pigments and Cool dyes will guarantee the optimum reflectance and thus the best solar-reflective performance.

A complete line of Cool pigments and dyes has been developed which exhibit good compatibility. Furthermore enough experience and data have been collected to match all major colours and to manage metamerism.

Testing the Cool effect

There are several ways to test if leather with a given colour is 'cool' or not. The most effective and scientific method—and the quickest—is to measure solar reflection using a commercially available VIS/NIR spectrophotometer. TFL has developed a test method for leather³ which is based on the now expired ASTM method E 903-96 under which solar reflection is measured at a fixed wave length of 980 nm in the NIR. The reflection figures obtained correlate very well with the measured temperature difference on the surface. A minimum reflection of 60% has been defined as the basis to guarantee that a good 'cool' effect will be obtained and that the leather can be called Cool. Another relatively simple method is to use a colour infrared camera where pictures are taken after exposing the leather to solar-like light for a given time as shown in *Panel 6*.

Panel 6: IR image made from black motorbike leather (Cool on the left and non-Cool on the right side)



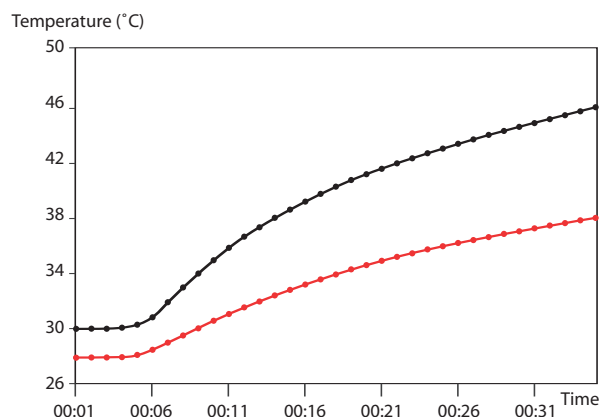
Cool leather applications

The most pronounced Cool effect can be achieved with darker surfaces and especially with black which produces the most obvious effect. In general TFL found surface temperature differences of up to 20°C between Cool and non-Cool black leathers and an 8-10°C difference can even be obtained on beige leathers. ➤



SOLAR-REFLECTIVE (COOL) LEATHER

Panel 7: Development of temperature inside a non-Cool motor bike suit (black curve) and a Cool suit (red)



An important application has been discovered in the area of garment leather, especially with garments for motorbike riders. Black is a popular colour with bikers and during summer bikers' leathers can heat up significantly. An IR image shows the differences recorded after exposure to sunlight in *Panel 6*, whereas *Panel 7* shows the temperature build up inside a biker's suit over time.

After 30 minutes of sun exposure a temperature difference of almost 10°C inside the biker suit could be measured. A similar situation can be found in the case of black shoe leather as used for dress and athletic shoes or boots. The IR image analysis shows a temperature difference of more than 10°C after 30 minutes of direct exposure to sunlight.

Another very interesting application for solar-reflective leather is certainly steering wheels, furniture and automotive upholstery leather—especially car seat leathers in convertible cars as shown in *Panel 8*.

Similar to garments and shoes a convertible car is an 'open air' application where no convection heat can build up in the surrounding area due to the large air volume. In these cases the lower surface temperature achieved by the Cool effect remains the same for the entire duration of the exposure to sunlight. The temperature difference between Cool and non-Cool car seats is usually 15-20°C on black shades and 8-10°C on beige. In a closed car interior with a small air volume these temperature differences will not remain the same due to the fact that there is a relatively small air volume inside the car which will heat up over time and the Cool leather will slowly assume the surrounding temperature due to convection. In field tests TFL was still able to record a temperature difference of approximately 10°C on the leather surface when comparing Cool and non-Cool car seats which more or less remained constant for the first couple hours of sunlight exposure. This is shown in *Panel 9*.

Only after 4-5 hours do the two curves for Cool and non-Cool car leathers slowly begin to merge. Therefore, if the entire interior of a car (i.e. seats, dashboard, side panels, and steering wheel) were made of Cool leather, although there are no firm figures yet available, there is the potential to save energy in terms of air conditioning. However, as TFL has discovered from its other Cool applications such as roof tiles, by increasing the typical reflectance value from an average of 10% to 60% the cooling energy usage can be reduced by more than 20% in warm climates⁴.

The window panes of some cars are equipped with special coatings which provide NIR reflecting properties, but their NIR

reflectance is only half as good as the one achieved by Cool leather. Therefore a measurable temperature difference between Cool and non-Cool leathers still remains.

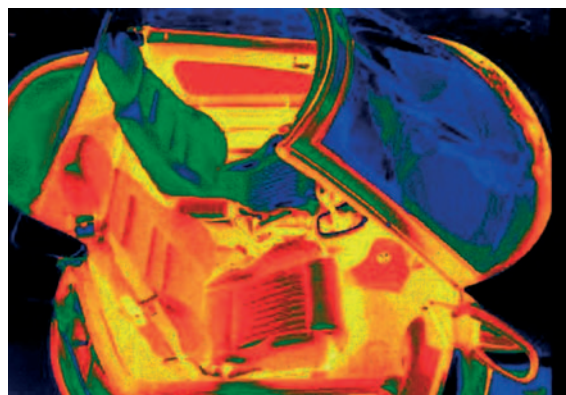
Ageing behaviour

As seen in the examples above, Cool coatings can reduce surface temperatures significantly, especially with dark or black colours. According to the Arrhenius equation where the speed of chemical reactions is a function of temperature, a temperature increase of 10°C doubles the speed of a chemical reaction, therefore Cool coatings are also expected to have a positive impact on the longevity or durability of leather. Although, this effect has not been found when conducting regular ageing tests where the heat is usually applied, in modified tests where heat is only generated through solar exposure, as in real life, a tendency towards better physical properties was noted with Cool leather. In order to see more significant differences, longer exposure and testing times need to be considered.

Although the temperature of an object or material certainly has an influence on ageing the greatest impact is generated by the UV/VIS part of the solar spectrum. The high energy UV waves can break chemical bonds thus generating free radicals which induce further reactions leading to a continuous disintegration of a material.

Accordingly, an optimal ageing behaviour can be achieved by using Cool finish coats in combination with an optimised light stabilising system.

Panel 8



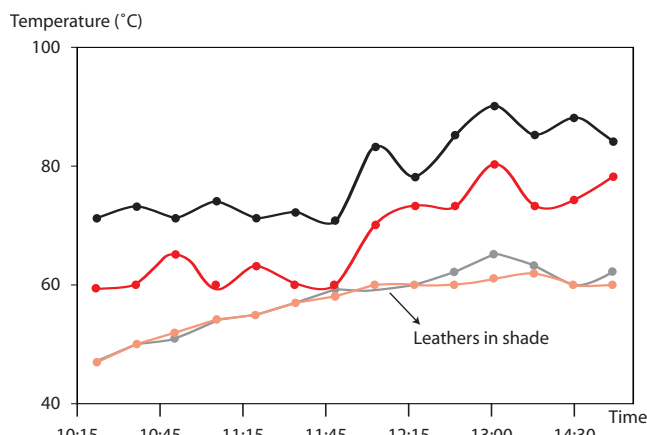
(a) Colour IR image of Cool (green seat) and non-Cool car seat (red) in a convertible car during exposure to sunlight. Average temperature difference is 15-20°C.



(b) Black and white IR image of Cool and non-Cool car seats and dashboard. The cool car seat and dash board appears in light colour as it reflects NIR waves.



Panel 9: Temperature development on Cool (red curve) and non-Cool car leather (black curve) in a closed vehicle over a period of 4hrs 15mins. The curves with less intense colours represent the temperature of the same leathers in shaded conditions.



Maximum Cool effect

To take advantage of the inherent solar-reflective properties of the collagen matrix of leather and to achieve the best possible reflectance, it is critical to use only selected Cool colours to dye the crust and only Cool pigments in the finish coat. The Cool

effect can be significantly reduced if even small amounts of non-Cool pigments are present. It is advisable to ensure best production hygiene, ideally using separate equipment for the manufacture of Cool leather. Residues of non-Cool pigments in containers and in the pipes of the spraying equipment can cause contamination and thus reduce the effect when the dust and fibres from non-Cool leathers are absorbed on the surface of the Cool leather during milling. In general dirt build-up on the surface should be avoided as it also can reduce the solar reflectance and thus the Cool effect.

Cool technology for leather can deliver new interesting features and applications. First it can improve the comfort of black and other darker shade leathers, and second it offers benefits such as energy savings in closed vehicles and a positive influence on ageing. In addition, Cool leathers have a more natural feel and appearance which combine very well with the comfort effect.

Acknowledgements

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