Solar reflective leather

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Abstract

When dark coloured leather articles are exposed to direct sunlight, they normally become very warm. So much so that in the case of interior surfaces of cars, the seats and steering wheels can be too hot to touch.

The solar energy from the near-IR and IR region of the solar spectrum are responsible for this heat build-up. Technology is now available to create leather that has solar reflective properties. Leather treated with these specific dyes and pigments will have an improved thermal comfort, for example, surface temperatures can be up to 30°C less. In addition, this lower heat build-up can provide additional benefits like improved shrinkage properties.

The paper will present the physics behind this development and the improvement in performance properties that can be expected from leather.

Dark leather in direct sunlight

Dark colours have always been in fashion for leather. Black is a favourite colour for shoes, upholstery articles, garments and even automotive interiors. Dark leather looks elegants and classy and in contrast to some lighter colours it is quite easy to care for. However, on warm days everybody can feel the one disadvantage of dark leather: Subjected to direct sunlight, it becomes extremely hot, unbearingly hot even, as the surface temperature of black leather can reach 85 ºC (185 ºF) or more in the sun. Touching a steering wheel, wearing a biker's suit or sitting on a seat made of dark leather can be very uncomfortable on a warm and sunny day.

At first sight it seems to be nature's law that dark materials become hot if subjected to solar radiation. A material is black because it absorbs all colours of the visible spectrum and reflects nothing, whereas if it is blue, it only reflects the blue component of the visible radiation. Radiation that is absorbed by the material can be transformed into heat and the temperature will rise, especially on the surface.

Energy distribution of solar radiation

It was already discovered by Friedrich Wilhelm Herschel (1738 – 1822) that solar radiation does not only consist of visible light. Herschel performed a famous experiment that led him to the discovery

of infrared radiation. He used a prism to separate the different colours of the sunlight and measured the temperature by holding a thermometer into the differently coloured light beams. For the visible part of the light, he observed a certain increase in temperature. When he moved his instrument beyond the violet part of the light, he observed no increase compared to room temperature (his thermometer was not very precise). But at the other end of the visible spectrum, beyond the red light, the temperature increase was significantly higher than for any visible colour. In this way, Herschel discovered IR radiation (see fig. 1).

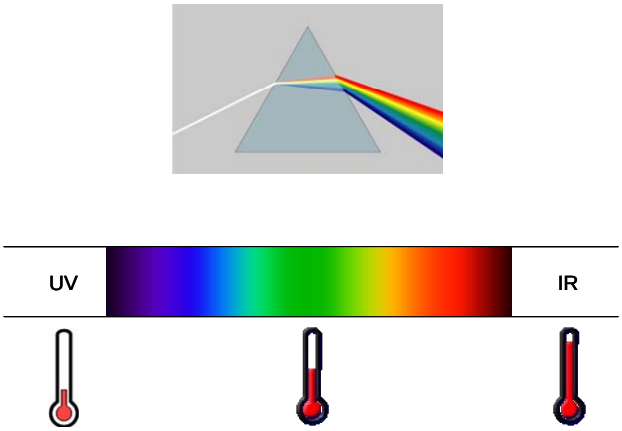

Fig. 1: Herschel's discovery of IR radiation

Today, we can still learn from this experiment, because it shows us that the energy content of IR radiation is higher than that of visible light! This means that the temperature increase of a material in the sun is to a large extent caused by IR radiation. In fact, 51% of the solar energy is emitted in the form of IR radiation and only 44% as visible light.

Solar reflective leather

Measuring the reflectance of a standard black leather in the visible and IR range, we can see that it absorbs almost all the visible light, but also almost all the IR radiation. While the first is necessary, because otherwise the sample wouldn't be black, the latter is not necessary at all for the appearance of the leather, but it is responsible for the high temperature of dark leathers in the sunlight.

We have recently invented a new solar reflective leather, which maintains the absorption of the visible light to achieve the different colours, but will reflect a large extent of the IR radiation (see fig. 2).

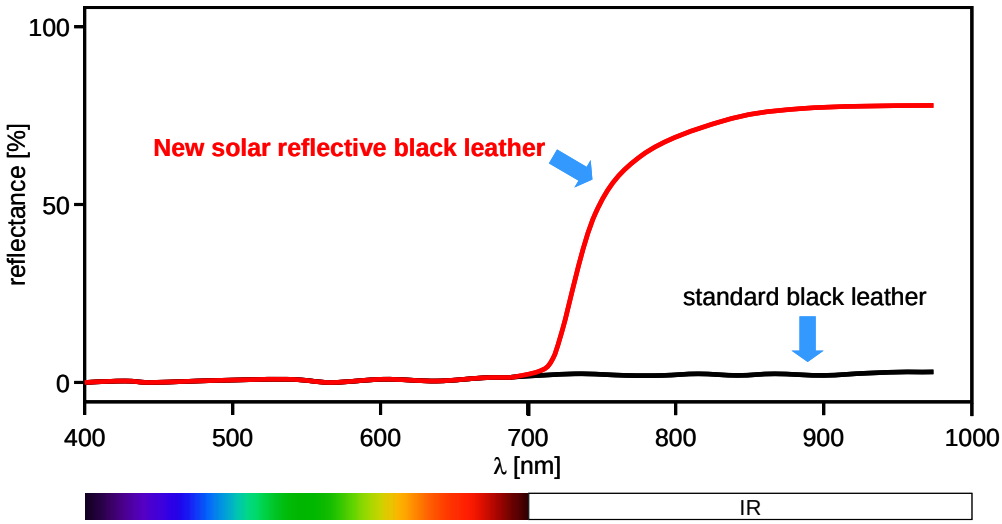

Fig. 2: Reflectance of visible and IR radiation by standard and solar reflective leather

The result of this invention is a significantly lower temperature at the surface of the solar reflective leather compared to a standard leather when subjected to sunlight. This difference can be up to more than 30 ºC for a black leather (see fig. 3) and it will still be very striking for other colours like blue, green or even red.

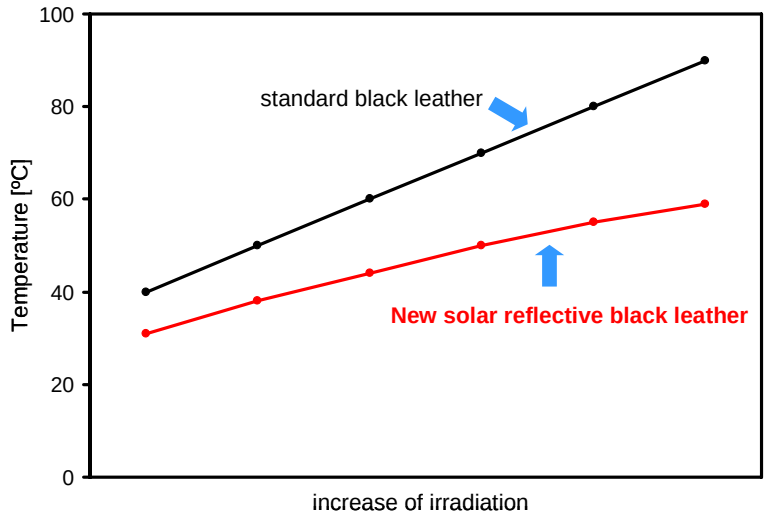

Fig. 3: Surface temperature on standard and solar reflective leather

Applications for solar reflective leather

The practical relevance of this effect has been demonstrated by the following experiment: A car was fitted with a leather interior partly consisting of standard black leather and partly of solar reflective black leather. With the car in direct sunlight, the surface temperature of the leather was measured after defined intervals of time. Leather surfaces that were exposed to direct sunlight and surfaces which were shaded (e.g. by the roof of the car), were measured separately. Fig. 4 shows the striking

result: Whereas in the shaded parts no big difference can be found between standard and solar reflective leather, it is evident that the solar reflective leather stays significantly cooler in direct sunlight. It has to be pointed out that the car used for the test was fitted with slightly tinted windows to reduce the heating up of the car interior!

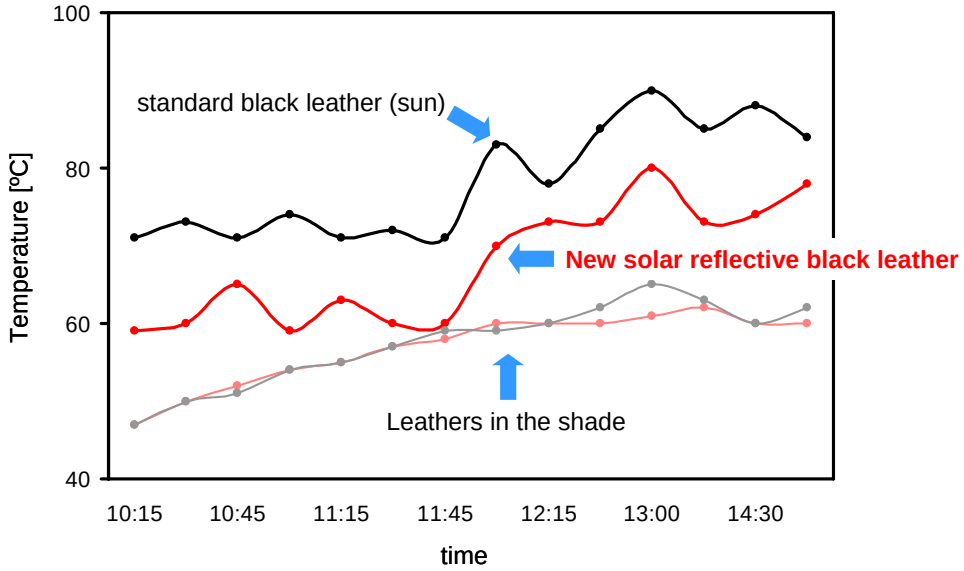

Fig. 4: Surface temperature on car seats

In a convertible, this effect is even more pronounced as can been seen from the picture below (Fig. 5), which was taken with a special heat sensitive camera. It can be clearly seen that the left seat, fitted with solar reflective leather, remains significantly cooler.

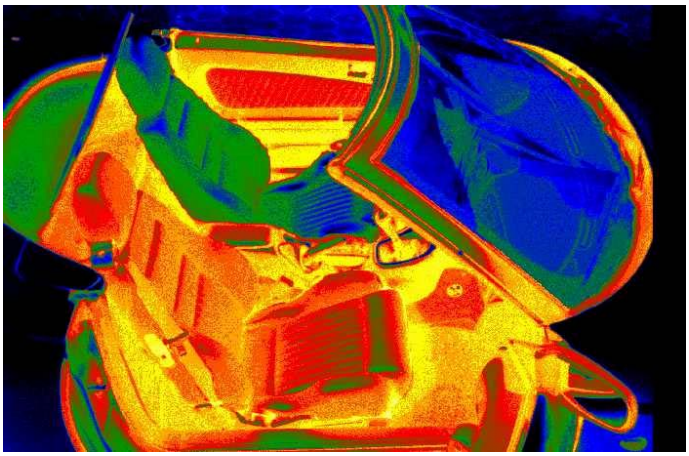

Fig. 5: Car interior photographed with heat sensitive camera.
Surface temperature indicated by colour

Wearing garments made from black leather can be very uncomfortable in direct sunlight. With another experiment we tested if this can also be improved using solar reflective leather. From the

evidence presented before it is now obvious that the surface temperature on the outside of two leather jackets, made from standard and solar reflective leather respectively, will be very different. This is again demonstrated by fig. 6 and 7, showing pictures taken with a normal camera and a special heat sensitive camera.

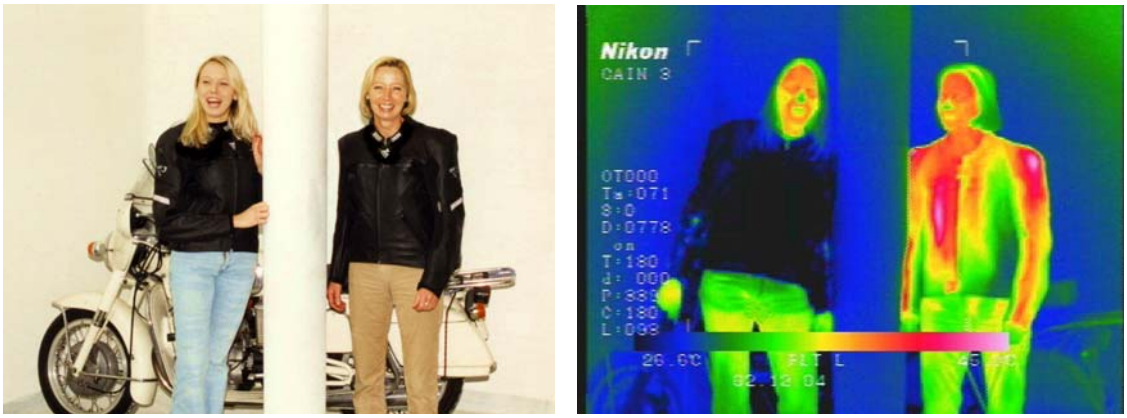

Fig. 6 and 7: Black leather jackets photographed with normal (left picture) and heat sensitive camera (right picture). On each picture the jacket made from solar reflective leather is on the left.

But will this have an effect on the temperature <u>inside</u> the garment? This was tested by measuring the inside temperature of a biker's suit exposed to sunlight. The result is shown in fig. 8, indicating that for example after about 20 min in the sun, the temperature inside the solar reflective suit is at about 35 ºC, whereas it is at about 42 ºC inside the suit made from normal leather. The difference of comfort wearing the two different garments is absolutely striking.

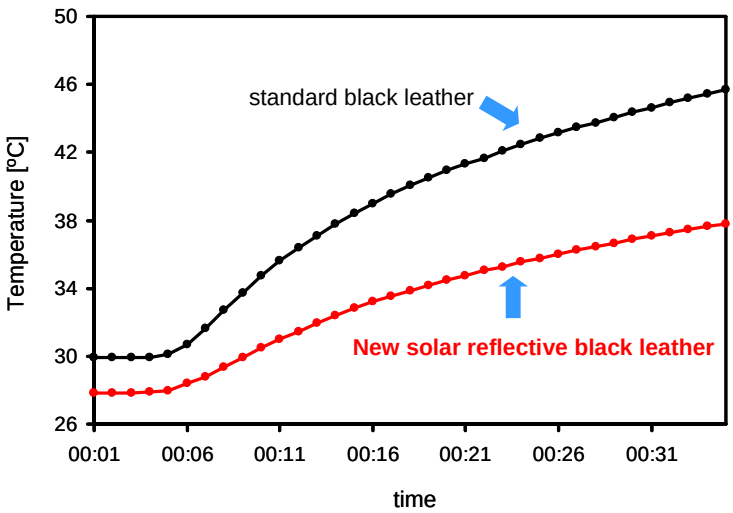

Fig. 8: Temperature measured inside biker's suit exposed to sunlight

Physical background

If no dyes or pigments are added, leather will reflect most of the IR radiation which is responsible for the temperature increase at the surface. This means that an un-dyed crust is a material with very good solar reflectance! It can be assumed that this reflectance is due to the structure of the papillary layer which will scatter and reflect the infrared radiation.

The fact that a finished leather article is normally not solar reflective is due to the use of dyes and pigments which absorb a major part of the IR radiation. There are two possibilities how to replace the standard products: The first option is to use dyes and pigments which are by themselves reflective for IR radiation. The second option is to use dyes and pigments, which do neither absorb nor reflect IR radiation.
Because leather is such a good solar reflective material, it has turned out that the second option is much more effective for this material. Following this approach of course means that all colourants used during the production of solar reflective leather need to fulfill the criteria of neither absorbing nor reflecting IR radiation. For this purpose we have developed a full range of both dyes and pigments for the production of solar reflective leather.

Additional benefits

Obviously, the increase in thermal comfort is the most immediately visible benefit of the new technology. However, reducing the surface temperature of the leather has additional beneficial effects for the material itself.

One of these benefits is an improved shrinkage behaviour under dry conditions. It is well known that leather will undergo a partly reversible shrinkage if exposed to high temperatures under dry conditions. This is not as dramatic as the destructive shrinkage under wet conditions above the shrinkage temperature. After several cycles of high temperature/low humidity and relaxation at low temperature/high humidity an area loss of 20% may be found for chrome tanned leather and significantly less for FOC (free of chrome) leather. Leather is mainly subjected to high temperatures if it is exposed to direct sunlight. The temperature of solar reflective leather in direct sunlight is significantly lower than that of standard leather. Therefore the area loss of solar reflective leather will be lower under these conditions.

Summary

Solar reflective leather can be produced by using a range of specially developed dyes and pigments. These colourants neither absorb nor reflect IR radiation, the leather produced will to a large extent reflect IR radiation due to its microscopic structure.
The surface temperature of solar reflective leather in direct sunlight is significantly lower than that of standard leather with differences of up to 30 ºC.
The effect can be used to increase thermal comfort for products like automotive seats, garments and also other leather articles. Lowering the temperature of leather exposed to sunlight will also be beneficial for other properties like the dry shrinkage behaviour of leather.