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UNDERCOVER INFLUENCES

Primer colour modifies appearance of effect finishes in unexpected ways. By Werner Rudolf Cramer, Consultant.

The colour of an undercoat layer substantially affects the overall colour impression when the paint layer over it is translucent, as in automotive applications, where effect basecoats are used. The appearance of a red interference colour finish is found to be affected less by applying it over a complementary coloured (green) filler than over red, red-violet or grey.

Colours are perceptions that occur in the brain. The pairing of real optical stimuli and virtual images generates colour information that we connect with objects. The virtual images consist of ideas that we have about and connect with colour.

Ultimately these processes lead to actual perception. This is induced by physical light rays that hit the retina of the eye and trigger an optical stimulus there.

Whatever happens before our eyes has nothing directly to do with actual colour perception. It is the translation of physical light rays into physiological colour perceptions which we experience, and these are influenced by psychological aspects. For example, this relates to the mixing of colours, which includes not only direct mixing but also the indirect mixing of colour in layers.

SOME EFFECTS OF COLOUR MIXING CONSIDERED

Paint colours are usually created using pigments that are not simply spectral red or blue but whose optical properties generate (for example) a red, which when lightened with white pigment can drift clearly towards violet. The blue can shift to a more intense blue.

Pigments in different paint layers similarly lead to colour mixtures. An example of this is the use of coloured or grey filler in the automotive sector. The filler colour here should compensate for the transparency of the overlying basecoat, i.e. the colour of the not-quite-opaque basecoat is reinforced by the underlying filler.

The individual components – paint layers and pigments – can be differentiated from one another as little with our eyes as with colour measurement instruments. What is observed in both cases is the overall colour impression. The different aspects are illustrated in two different trial series. One deals with an individual interference pigment and the other with a real commercial automotive series colour.

THE NATURE OF INTERFERENCE PIGMENTS

Many interference pigments are transparent and show two colours or colour effects. They consist of a carrier material that is coated with a strongly diffractive layer of a metal oxide – for example titanium oxide. The surface of the pigment reflects part of the light falling on it and this also happens on the interfacial layer with the carrier material. Both parts of the light interfere with each other and typical reflection colours are generated. These are particularly dependent on the layer thickness of the metal oxide and on the angle of the light.

Similar processes take place on the rear side of the pigment, although the resulting transmission colour is complementary to the reflection colour because of the missing phase shift. For example, a pearl green

RESULTS AT A GLANCE

➞ The appearance of a paint finish – viewed subjectively or instrumentally – is affected by many factors. The colour of an undercoat has a decisive influence on the overall colour impression when the paint layer over it is transparent. This is often found in automotive applications where effect basecoats are used on grey or coloured fillers.

➞ Interference pigments have both a reflection colour and a complementary transmission colour, whose relative strength depends on the viewing angle, and also on the absorption of the undercoat.

➞ If the filler colour does not correspond exactly to the basecoat colour, the colour changes. Red or red-violet filler colours shift the overall colour impression; grey fillers also affect the colour substantially. As a green filler reflects equally little in the red spectral range, it barely affects the colour of the basecoat in this range.

reflects strongly in the green spectral range. When examined, the corresponding complementary colour appears in the red spectral range.

HOW UNDERCOATS AFFECT OVERALL APPEARANCE OF BASECOATS

The transparency of these types of interference pigments leads to a strong dependence of the overall colour impression on the undercoat colour. If a transparent interference pigment is used in a basecoat system and this is applied to a black and a white undercoat/filler, the results show two extremes: the black undercoat absorbs nearly all light rays that fall on it, and the white reflects nearly all. And the complementary transmission colour of the interference pigment is also reflected from the white layer, but not from the black (*Figure 1*). This same effect presents itself in both visual colour matching and with instrumental measurement: the reflection colour can be identified close to the gloss angle. In the region between 20° and 30° from the gloss angle there is a transition area in which the change to the complementary transmission colour takes place.

This change can be illustrated when the corresponding colour values are plotted against the measurement geometries. With a green interference pigment, the change between the green reflection colour and the red reflection colour becomes visible when colour value a* from the L*a*b* system is selected (*Figure 2*).

The reflection over a black undercoat is lower than over white. With a green interference pigment, the red transmission colour is reflected by the white undercoat. As the light is separated into reflections and transmissions, both parts together produce white again. While the chroma over the white undercoat first decreases as the angle from the gloss (aspecular angle) increases and then rises again after the transition area, it reduces continuously over the black undercoat.

A similar result can also be seen for the brightness: it is higher over the white undercoat than over the black. This also first decreases with increasing aspecular angle and then rises again. Over a black undercoat it falls continuously (*Figure 3*).

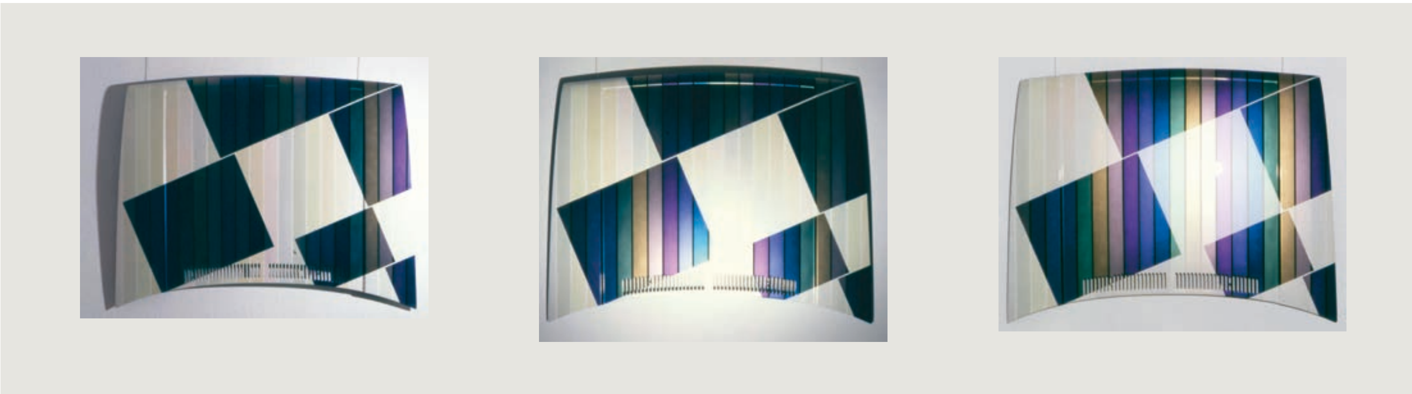
MEASUREMENT PROCEDURES AND THEIR LIMITATIONS

Measurements were carried out using the most up-to-date devices – X-Rite “MA98” and “BYK-mac i”. It is important to note here that the measurement angles are not at equal distances. The difference between measurement positions increases in unequal steps; in this respect, the statements relate generally to these measurement geometries.

Interference pigments can be measured in a limited way with both devices. The interference of a pigment or a paint is shown by changes in the incidence angle of the light. The BYK device offers just one illumination geometry and the X-Rite offers two. The interference can sometimes be shown by a trick; it must be noted however that the results depend strongly on the type of application (see *Figure 4*).

The trials show the dependence of transparent pigments on the undercoat colour. White and black represent the two extremes. In between are graduations of grey or coloured undercoats. Both options are applied both in automotive OEMs and also in repair painting (refinishing).

Figure 1: This bonnet has first been painted in white (solid), and then the surfaces have been painted in black (solid). From left to right, the stripes have been painted with different interference colours. Depending on the viewing angle, reflection or transmission colours can be identified over the white undercoat. Over a black undercoat only the reflection colours are visible, since the undercoat absorbs the corresponding transmission colours.



EFFECTS OF BASECOAT COLOUR CONSIDERED

The search for better methods of application – whether with or without colour – often reaches philosophical dimensions, although the factual situation is clear: the overall colour impression determines the result, both in terms of visual assessment and also in instrumental measurement. And the overall colour impression consists of different components.

Firstly, a large part of the light is reflected from the basecoat. This reflection can consist of reflections from reflective aluminium pigments and those from and within interference pigments. Absorbing colour pigments scatter the light – including the light reflected from the other pigment types – in all directions.

The processes in the basecoat are very complex, as here different types of pigment and their different optical properties come together. The trans-

Figure 2: Viewed in the transition area between 20° and 30° from the gloss angle, interference pigments change to the transmission colour. The change of "Kuncai Stellar Green" from green to red over a white undercoat is shown in terms of its a* colour value.

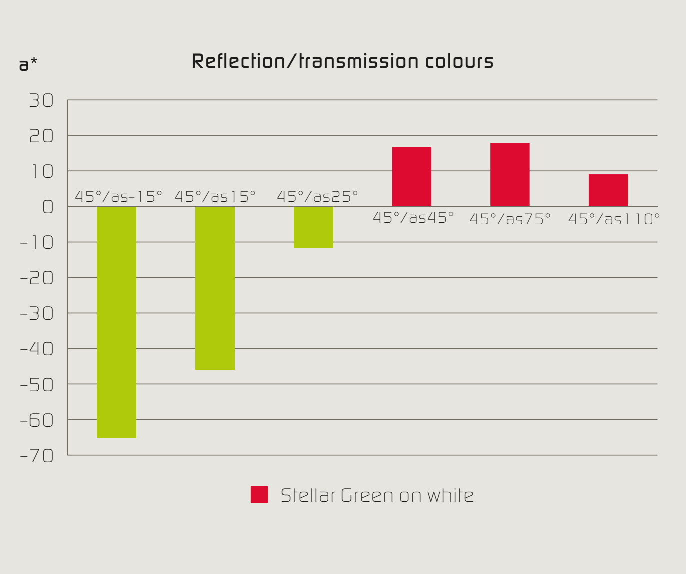


Figure 3: Reflectance is higher over a white undercoat than over a black undercoat. In both cases the reflections shift to shorter wavelengths when illuminated at a flatter angle (here from 15°/as15° to 45°/as- 15°).

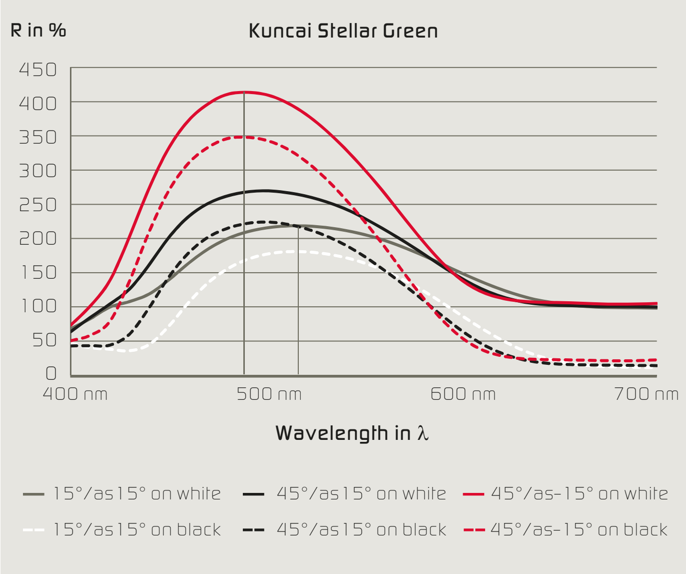


Figure 4: The interference line consists of the geometries 15°/as15°, 45°/as15° and 45/as- 15°. Over a white undercoat, the complementary red transmission colour is identifiable at geometries far from gloss.

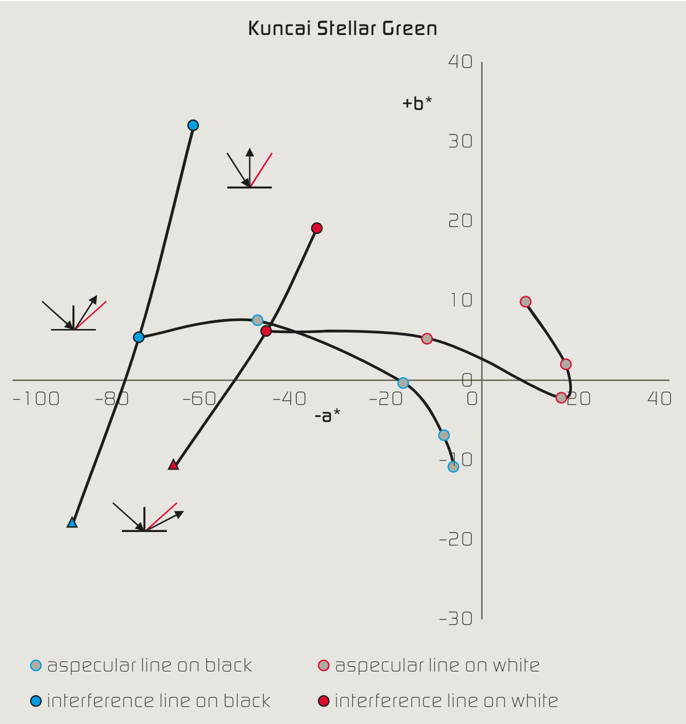


Figure 5: The colour lines (aspecular lines) in the sample deviate from the reference sample over the grey graduations, especially at large aspecular angles. Colour values are summarised here as lines from 45°/as110° (left) to 45°/as- 15° (at right).

parent basecoat acts like a transparent colour film with white light shining on it. Part of the light is reflected, another part is absorbed and a further part leaves the film through the other side.
This proportion of the light is also subject to complex optical processes in the basecoat and then hits the undercoat. And depending on the colour, it receives different treatment here. A red undercoat appears black when it is irradiated with green light, and vice versa.
In order to report the possible effects of a transparent basecoat on a coloured or grey filler, a test series was initiated with a standard red colour.

EVALUATION OF A COMMERCIAL RED SHADE EFFECT COATING

Materials were acquired from PPG Refinish and the standard Peugeot colour "Lucifer Red" was mixed according to paint formulation. The filler colours were simulated with tinting paints: one green, one red and one red-violet tinting paint.
All mixed paints were applied by air spray to sample panels according to the manufacturer's instructions. And all mixed paints were also mixed with white paint in the ratios 80:20, 60:40, 40:60 and 20:80 and correspondingly applied.
In a second series, grey tones were created in line with recipes stipulated by PPG Refinish as grey graduations from SG01 to SG06 (Spectral Grey). Then the red effect paint was sprayed as a basecoat on all painted sample panels in two layers.
As a reference, a further panel was sprayed with the basecoat until no transparency could be identified (referred to below as opaque red). All sample panels were then sealed with a high solid clearcoat.
Colour of the sample panels was measured using the X-Rite and BYK instruments Both devices measure at - 60°, - 30°, - 20°, 0°, + 30° and + 65° in absolute values. These geometries correspond to - 15°, 15°, 25°, 45°, 75° and 110° from the gloss angle (aspecular) at an illumination of 45°.
Both the reflection colour and the a* b* colour values were assessed, each time against the values of the reference sample. The geometries quoted above were used in the presentation of the a* b* colour values. The focus of the assessment of reflection values was the geometries of as15° (aspecular 15°) close to the gloss and as45° (aspecular 45°) away from gloss. These geometries are created by illumination at 45° and the observation/measurement at - 30° and/or 0°.

MEASUREMENT PROCEDURES USED

"Lucifer Red" is a typical OEM colour; depending on paint formulation, it may contain one or several interference pigments. These ensure that the colour shifts through to yellow when it is viewed flatter at the gloss angle. This can be read from both the reflection curves and in the a*b* values.
As the two measurement devices are not equipped to perform flat illumination, a geometry of 45°/as- 15° can be used instead. It corresponds in reverse to the light beam of geometry 60°/as+ 15°. It must however be noted that this method depends on the application: draw-down basecoats show differences from sprayed-out basecoats. As long as the application has been done in the same way, the method can be used in all cases.

HOW UNDERCOAT COLOURS ACT ON THE EFFECT COATING

Certain quite basic facts should be considered in the assessment of the results. Firstly, the red basecoat has an effect on

the light falling on it similar to a red film that lets red light through. Secondly, the only light rays that can be reflected from the undercoat are those that actually reach it.
Thus the maximum reflection is with a white undercoat and the minimum with a black undercoat. Theoretically, grey colours absorb equally across the entire spectral range. In practice however, black pigments (mainly carbon black) also have effectively a colour component: a carbon black with fine particles is bluer than one with coarser particles.
In this way, the red light of the basecoat will not be reflected equally. The best result – in the sense of correlation with the reflection curves – was found with Dark Grey, when the sample was viewed and measured close to the radiance (45°/as15°).
The lighter and darker grey colours resulted in significant deviations from the reflection curve of the reference. The assessment of the a*b* colour values additionally showed the side drifts of the colour value at larger aspecular angles from gloss (see *Figure 5*).
The rather basic facts also apply to a coloured undercoat: the only parts that can be reflected are those that are not absorbed. A green undercoat colour reflects in the green spectral range while it absorbs the light rays in the red area. If the reflection curves in the green trial colours are compared with those of the reference colour, it becomes clear that less is reflected in the red area (*Figure 6*). The a*b* colour values of the sample over the green undercoat show good correlations with the colour values of the reference at all measured geometries (see *Figure 7*).

RED UNDERCOATS GIVE COLOUR DEVIATIONS WITH RED EFFECT COATINGS

In contrast to this, great deviations arise when the base paint is applied over red and its mixtures with white. This is particularly true for geometries far from the gloss angle. It can be seen here that different reflection parameters influence the overall colour impression significantly, i.e. when the red of the undercoat deviates from the red of the basecoat, there is a colour shift.
The mixtures of red paint with white show the behaviour typical of a lightening range: the chroma increases with the addition of white firstly up to a weight ratio in the mixed paint of 60:40. At the same time, the yellow proportion of the colour decreases. The resulting colours deviate significantly from the reference sample (*Figure 8*).
Similar results arise when using red-violet and its mixtures with white as an undercoat colour. With red-violet too, the colour drifts towards blueish when the red-violet mixed paint is lightened with white. In contrast to the red graduations, the reflections of the blue-violet graduations are within the reflection range of the basecoat.
With red-violet too, the resulting colours deviate from the reference sample, particularly in the geometries far from gloss. Overall however, the deviations are less than with the red mixtures.

WHY AN UNCONVENTIONAL FILLER COLOUR MAY BE BEST

The colour of an undercoat – for example that of a filler – has a decisive influence on the overall colour impression when the paint layer over it is transparent. This type of paint system is often found in automotive applications where basecoats are used on grey or coloured fillers.
The overall colour impression then depends on the choice of colour and also on the choice of grey tone. If the colour of the filler does not correspond exactly to the colour of the basecoat, the colour changes. A filler can only reflect light rays in accordance with its pigmentation.
Applying a red basecoat on a green filler at first seems absurd. But as the green filler reflects equally little in the red spectral range, it barely affects the colour of the basecoat in this range. Red or red-violet filler colours have a stronger influence on the red basecoat and shift the overall colour impression.

Figure 6: The reflection curves of the selected green samples (80:20 and 20:80 with white) reflect less in the red spectral range. The reflections barely differ from the reflections of the reference when the basecoat is applied onto it.

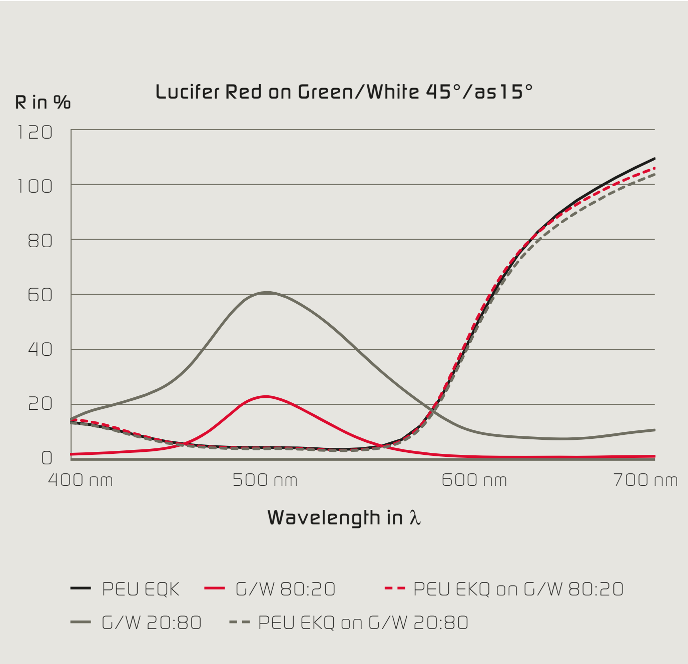


Figure 7: The best correlations arise when Lucifer Red is applied over green. All mixtures of green with white show as undercoat colours with colour values closely approaching the value of the reference sample. Colour values are summarised as lines from 45°/as110° (left) to 45°/as-15° (at right).

"The transmission of a basecoat depends not only on its pigmentation, but also on its application."

Werner Rudolf Cramer
Consultant
wrcramer@muenster.de

3 questions to Werner Rudolf Cramer

Can the transmission colours of the basecoat be incorporated into a masstone recipe? *If the masstone recipe takes account of several measurement angles, the transmission colour is used in the calculation of the recipe. However, it is not specifically stated.*

Are there any ways to incorporate corresponding components into the masstone recipe of the filler so as allow for transmission? *The transmission of a basecoat depends not only on its pigmentation, but also on its application. In this respect, no general allowance can be made for the filler recipe.*

Which components influence the transmission of a basecoat? *First and foremost, the transparent or semi-transparent interference pigments. But nano-pigments which are used in a medium clearcoat (e.g. PPG-Andaro in "mid-clear" for Ford's Ruby Red series of colours) provide great transparency. Different components come together, producing in some cases a play of reflection and transmission. And in other cases, producing colour reactions of the kind found in coloured films.*

Figure 8: Significant deviations can be seen from the reference red effect basecoat colour particularly in the area far from gloss. Colour values are summarised as lines from 45°/as110° (left) to 45°/as- 15° (at right).