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Mix and Match

The interplay of various pigment types in strategic colour design

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In paint formulation, achieving the right colour depends on the pigments used. When conventional pigments and modern effect pigments are mixed, many things have to be considered to obtain the desired result.

Just as in other fields of application, the creation of colours for motor cars depends on the choice of pigments. They dictate what colour ranges and effects can be achieved. Availability can, however be an issue. For example, health and safety and environmental protection issues forbid the production of pigments with certain blue effects, thus curtailing their use in designing new colours. To ensure the optimal and cost-effective use of pigments, it is important to consider their optical characteristics. Conventional colour pigments (sometimes referred to as solid-colour pigments) usually display the same colour at all angles of illumination and observation and are therefore easy to understand. However, aluminium and interference pigments differ in appearance depending on the angles of the incidence of light and observation. I.e. the perceived colour and/or brightness of these materials vary. Conventional colours have an almost even distribution, while effect colours are more effective close to the gloss angle than far away from it. The following are the materials illustrated:

» 91002 solid_2 + White
» 91014 Aluminium Silver Dollar pure
» 91265 Aluminium Cornflake pure
» 91015 Pearl Blue pure
» 91237 pure Xirallic Galaxy Blue
» 91006 Aluminium Silver Dollar + solid_2
» 91019 Pearl Blue + solid_2
» 91229 Xirallic Galaxy Blue + solid_2
(solid 2 = mixture of blue, green and black solids)

Aluminium pigments appear to shine, because they reflect incident light directly, rather like a mirror. The closer the observation angle is to the gloss angle, the stronger the reflection. In some cases, the reflection parameters vary considerably, depending on the pigment type (e.g silverdollar or cornflake) and size. In contrast to conventional pigments, these angle-dependent characteristics must be taken into consideration when creating a new colour. A shift in the height of the reflection curves demonstrates these optical characteristics.

As their name suggests, interference pigments are distinguished by the optical-physical phenomenon of interference. The wave-length of their reflection colours shortens as the angle of illumination becomes flatter. For example, red moves towards yellow or yellow towards green when the angle of the light falling on it increases. Maximum reflection in the blue range can also move into the invisible UV range, while invisible IR can appear in the maximum visible red range.

The reflection colour of an interference pigment is always visible close to the gloss angle. However, if it is hidden due to the presence of a high level of colour or aluminium pigment, it makes no sense to use it. A transparent, blue interference pigment is also always visible close to the gloss angle when mixed with absorbing blue pigments. *Figure 1* shows an example of this. Here, a pearl blue interference pigment is mixed with solid-colour pigments. As the concentration increases, the interference line shifts almost in parallel with the colour pigment.
The interference line results from the colour travel when the geometry changes. As modern portable devices do not measure interference lines, a interim solution has been selected from the geometries 45°/-15°, 45°/15° and 15°/15° (illumination/aspecular in each case). The aspecular lines (grey, respectively 45°/15° - 45°/110°) all point in the same direction (the exception is the transparent pearl blue without admixture).
Interference pigments with strong colour travel are always identifiable in all possible colour combinations by their unique interference line as in *Figure 2*, where, in mixtures of such interference pigments with various solid-colour pigments or mixtures, the typical interference line for the interference pigment remains unchanged.
This is clear from observations or measurements at various illumination angles and the aspecular angle relative to the respective gloss angle.
The reflection colour is always visible close to the gloss angle, a fact to be kept in mind when creating new paints. Transparent interference pigments with specially coated platets have a transitional area between 20° and 30° from the gloss angle. At aspecular angles far from the gloss angle, absorption characteristics have the greatest influence on the overall colour impression. The transmission colour of these pigments, which is complementary to the reflection colour, also influences the overall colour impression at these difference angles.
Interference pigments are unique in two ways: They cannot be produced by mixing and, unlike colour pigments, their colour travel depends on angle.

Results at a glance

››› The creation of new car-paint colours is dictated by the pigments available. Their optical characteristics are a key factor.

››› Interference pigments produce interesting effects, because the perceived colour changes with the angle of observation.

››› Mixing interference and solid-colour pigments enlivens the colour palette.

››› The choice of pigments is crucial as mixtures can either increase or reduce a colour effect.

››› Transparent coloured or interference pigments have the biggest influence over the colour impression at a wide angle of observation.

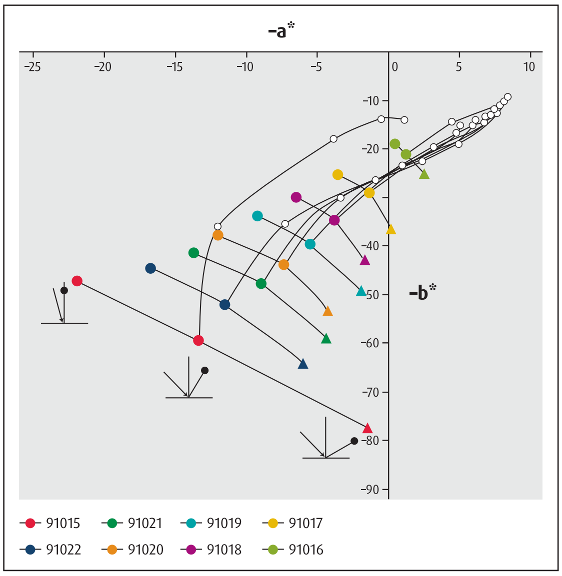

Figure 1: The shift of the interference line in mixtures of a pearl blue interference pigment with colour pigments at different concentrations

Visual observation

The most important aspect in evaluating effect colours is the geometry of illumination and observation. In the case of car paints, they are so-called off-plane geometries, i.e. observation is not on the same plane as that formed by the illumination and the perpendicular.
In-plane geometries are used in standard visual and instrumental observation and measurement methods. The geometries of portable measuring instruments do not match with those measured either at the testing-room window or in standard light booths. This is less obvious in colour formulations with aluminium or classical interference pigments than with modern interference pigments with a greater travel of colour.
In visual observation and assessment of sample panels at the window and in most light booths, the offset angle between illumination and observation is always the same. If the panel is held at the window such that you are looking at it at the gloss angle, the illumination angle is 15° from the perpendicular, for example. The gloss angle – and in this position also the angle of observation – is therefore -15°. The result is an offset angle of 30°

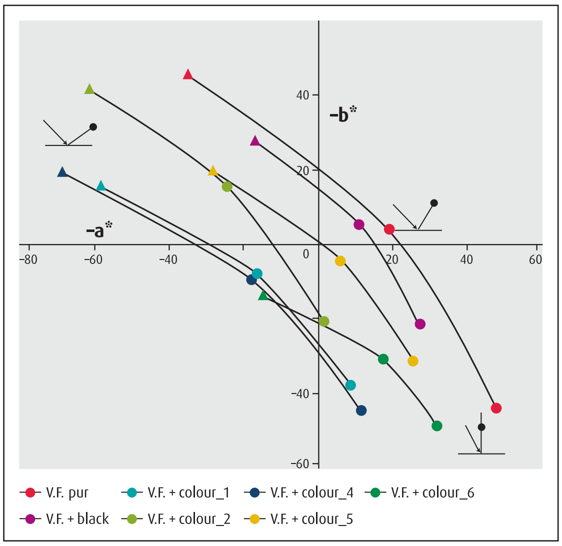

Figure 2: The unchanging, typical interference line of Colorstream Viola Fantasy, with various colour pigments or mixtures

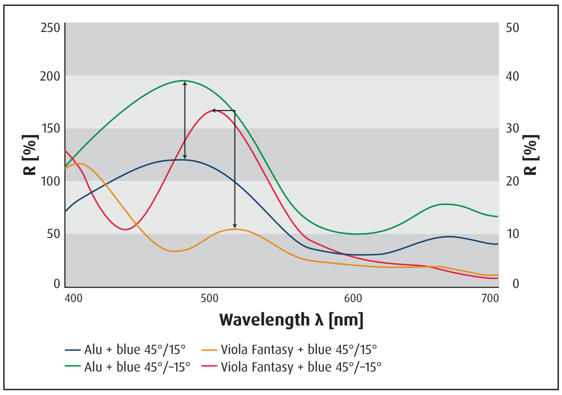

Figure 3: A comparison of geometries of 45°/-15° and 45°/+15°

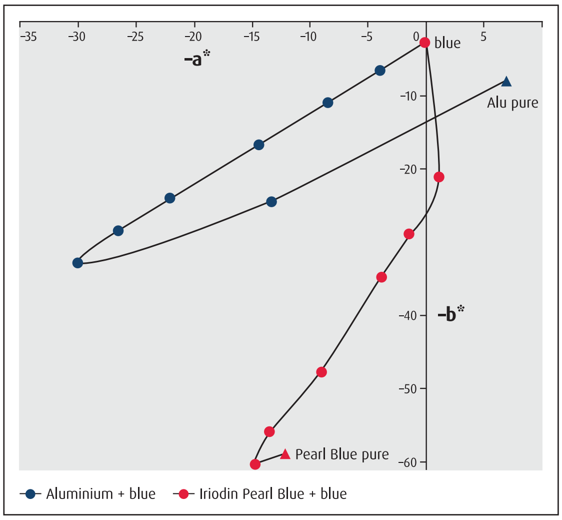

Figure 4: Mixtures of aluminium and pearl blue effect pigments with blue at 45°/15°

between illumination and observation. This remains the same when the panel is tilted backwards and forwards. The panel always remains in the cis-position when it is tilted towards the observer, it, i.e. the sample is always seen on the illumination side. If it is tipped it away from him, it is initially seen in the trans-position, i.e. on the opposite side of the gloss angle to the illumination. Tipping it further away, moves it into the cis-position.

Optical behaviour important

Unfortunately, current portable devices offer hardly any method of measuring interference. The -15° aspecular geometry established in the "ASTM E2539-12 Standard Practice for Multiangle Color Measurement of Interference Pigments" provides an interim solution. Comparing reflection curves at +15° and -15° enables coloured interference pigments to be distinguished from aluminium and white interference ones (see *Figure 3*). A significant difference regarding optical behaviour should be considered when creating new effect paint. Aluminium pigments and white interference pigments show an increase in their reflection when the observation point changes from the cis-position (+15° aspecular) to the trans-position (-15° aspecular).
Coloured interference pigments also demonstrate colour travel towards the shorter wavelengths.
The second illumination at 15° formulated in the ASTM standard practice is also helpful. With these measurement values and those at 45° illumination, an interference line can be created, although it is only a stopgap. However, it can be used to describe optical properties.
During visual assessment of effect paints at the window or in the light booth, the sample panel should not be tilted backwards and forwards. Rather, it should be viewed with arms outstretched against the light source. The arm is then moved downwards with the panel held parallel. Thus, the distance to the light source is simultaneously reduced, so that the sample is always viewed close to the gloss angle. In this way, the colour travel of the interference can be identified. This can be seen very clearly with the modern developments in interference pigments.

Bringing colour to life

The yellow, orange and red colour families are strong pigments that have high chroma and high lightness. Both characteristics have a disruptive effect when mixed with interference pigments, particularly transparent interference pigments which are less prominent when they are close to the gloss angle, because of the colour reflection. For the above colour groups, interference pigments whose platelets are coated with iron oxide or a combination of titanium dioxide and iron oxide are more suitable. This particularly applies to reds, which are very much in demand at present, intersesting colour reactions can be created with interference pigments coated with iron oxide.
Green, blue and violet are the most interesting colour groups for use with transparent interference pigments.
When aluminium and interference effect pigments are mixed with solid-colour pigments, similar behaviour is seen to that achieved by mixing solid-colour pigments with white (titanium dioxide). For example, if a yellow or red solid-colour pigment is mixed with white, the colour line travels from yellow or red towards white. Green or blue solid-colour pigments look black and become coloured only when diluted, i.e. by mixing them with white, the chroma and lightness increase initially, until the chroma peaks and then falls away again. Further addition of white makes the colour paler and lighter.
Similar behaviour is seen in interference pigments. A white interference or an aluminium pigment is brought to life by using them in mixtures. The overall colour impression initially increases in chroma and brightness. Once the peak, has been reached, only the lightness increases and the chroma falls away to create an achromatic effect mixture. This is illustrated in *Figure 4*. Mixtures of coloured interference pigments with solid-colour pigments show direct colour gradients between the pigments.
Interference and aluminium pigments can also be mixed with white pigment(titanium dioxide). However, the effects achieved are quite weak. Titanium dioxide pigment particles are comparatively large, which means that the effects may turn out to be inadequate.
Some specific features need to be taken into consideration when interference and aluminium pigments are mixed. Fundamentally, coloured interference pigments move towards shorter wavelengths when the angle of illumination becomes flatter. However, this travel is reduced and restricted by the presence of aluminium pigments. As from a certain mixture ratio, it is worth replacing a coloured interference pigment with a white version.

Samples painted with an aluminium pigment appear grey. Correspondingly, those painted in white interference pigments are perceived to be white. The panels, which are of a normal size, are studied vertically across their whole surface at an angle of about 20°. When observed close to the gloss angle, the reflection of the aluminium panel is stronger than the interference panel. The addition of white interference pigments would reduce its lightness close to the gloss angle.
Close to the gloss angle (illumination 45°/observation 60° = -15° aspecular), different pigments reflect differently: Silverdollar aluminiums (91014) reflect more strongly than cornflake aluminiums (91265), Xirallic Galaxy Blue (91237) more strongly than Iriodin Pearl Blue (91015).
The effect can also be changed with the addition of a flop controller or micronised titanium dioxide. This applies in particular to formulations containing aluminium.

Strategic approach

In most cases, a new paint is created by replacing the effect pigments in an existing formulation. The advantage of this method is that the formulation has been already used and tested. The disadvantage, however, is that it is impossible to predict how prominent the effect pigment will be in the formulation and how strong it may become. It is rather like putting a new F1 racing car engine in a small used car. It can give surprising results!
A strategic approach is always better. It is certainly possible to use existing formulations as a guide, but effect pigments are unique, interference pigments in particular. The choice of effect pigment should therefore be considered at the outset.
The intensity of an effect can be shown in a comparison between geometry close to and far away from the gloss angle. For example, aluminium pigments of the cornflake and silverdollar type and various types of interference pigments show comparatively strong differences in reflection between these geometries. *Figure 5* demonstrates that, away from the gloss angle (illumination 45°/observation -20° = 25° aspecular), the reflection of pigments such as aluminium Silverdollar and interference pigments reduces significantly, which illustrates the intensity of the effect.
Having chosen the colour range of a new paint and what effects are to be achieved, if it is decided to use one or more interference pigments, one begins with that which is intended to have the greatest influence on the overall colour impression. The work does not necessarily have to start off in the colour range required. The colour can be shifted with other interference pigments of the same type or of a different one. For example, a green interference pigment can be moved in two directions by adding a yellow or blue pigment. With a white or a red interference pigment, the interference becomes smaller and therefore the interference line as well. And with a white interference pigment, the mixture becomes paler.
Interestingly, transparent and other interference pigments can be mixed in almost any combination. As they obey additive mixing rules, a pearl green and a pearl red result in a whitish yellow. Adding a pearl blue to the yellow can make it travel in the direction of the colour

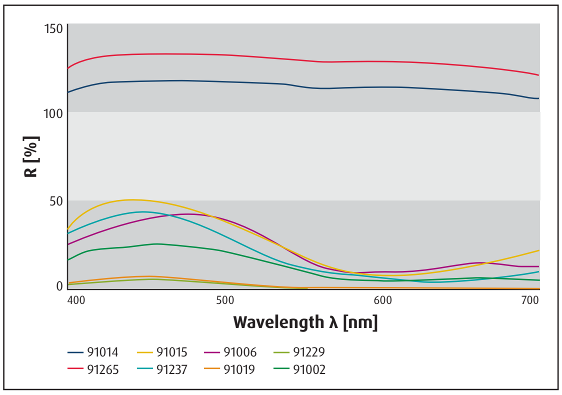

Figure 5: A comparison of the reflection of Silverdollar and interference pigments with other effect pigments

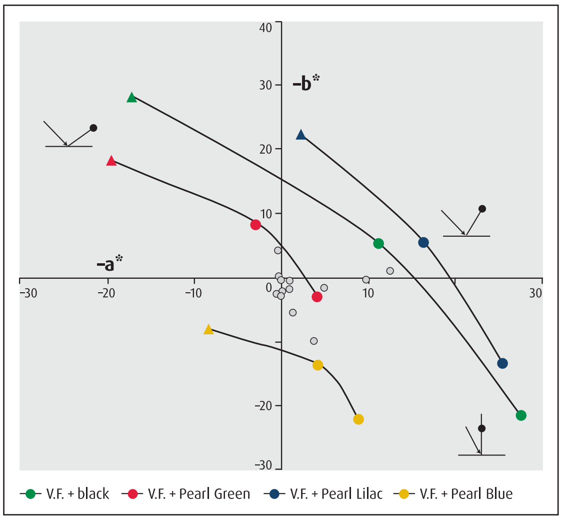

Figure 6: How the interference line shifts when differing interference pigments are mixed

position of the starting pigments. If, for example, a mix of Xirallic Stellar Green and Solaris Red together with a "dash" of Galaxy Blue gives an interesting white with a different sparkle effect to that of Xirallic Crystal Silver. As shown in *Figure 6*, the interference line can be shifted completely by mixing with other interference pigments. Here the black mixture of Viola Fantasy has been mixed respectively with Pearl Lilac, Pearl Green and Pearl Blue. The aspecular lines (grey) all run in the same direction.
At the next stage, absorbent, perhaps even transparent, colour pigments are added. Here it should be noted that these have the biggest influence on the overall colour impression at angles a long way from the gloss angle.
If interference and aluminium pigments are to be mixed, it is best to begin with the stronger partner in the mixture. In the case of an aluminium pigment, this is then added to the interference pigment required in order to create colour in the interference geometries (different illumination angles with the same aspecular angle). Although the aluminium pigment flop effect is substantial in terms of lightness, it can be altered by using an appropriate flop controller – if the interference pigment added has a crucial effect on the colour close to the gloss angle. The addition of solid-colour pigments and appropriate white pigments serves to steer the character of the aluminium and interference effects in a coloured or achromatic direction.