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SOPHISTICATED COLOUR MATCHING MADE EASY

A new method to characterise interference pigments. By Werner Rudolf Cramer.

Interference pigments are used in many automotive and industrial paint formulations to create a wealth of attractive effects. While manufacturers naturally focus on developing new visual experiences, it is also important to ensure instrumentation and test methods are similarly advanced. A new method identifies interference pigments rapidly and accurately, which benefits refinishing operations and OEMs as they seek to reproduce these colours.

Pigments manipulate the incoming light and partially reflect it. These reflected components trigger a colour stimulus in the human eye, which is transformed into a colour by the brain. This manipulation of light is described by physics as the transformation into a colour by physiology. However, we cannot identify how the manipulation really happens. For example, if we mix a red and a yellow pigment to create orange, then this orange may look the same as an orange pigment but the blend's reflectance curve has a typical saddle

Table 1: The values s1 to s6 characterise the interference pigments with colour-like pigments being easier to distinguish.

	Pearl green	Stellar green T60-24	Pearl blue	Galaxy blue T60-23	Pearl red	Solaris red T60-21
s1	166	175	381	367	774	770
s2	843	809	889	886	799	769
s3	2033	929	2664	1485	2709	1420
s4	940	818	895	1314	724	857
s5	9	984	270	253	573	539
s6	843	809	889	886	799	769

RESULTS AT A GLANCE

→ Interference pigments have been difficult to characterise in the past. Cutting-edge paint effects require cutting-edge instrumentation and test methods.

→ A new method will become a simple tool for refinishing applications to characterise pigments.

→ Measurements from sample panels produce interference and aspecular lines, which are used to calculate six defined parameters and identify the interference pigments

→ Experiments to test this method successfully characterised different pigments and demonstrate its effectiveness as an aid in colour reproduction.

that lacks the orange pigment. In principle, pigments reflect in the entire spectral range, for example, a green pigment reflects in the green spectral area and also in the red, yellow and blue – only much weaker.

The reflected colour is the typical colour of an interference pigment that results from multiple reflections and refractions in the interference pigment. The resulting reflection colour depends, among other things, on the strong refractive metal oxide that surrounds the carrier platelet and its layer thickness. Both factors are determined by the producer and the user has no influence on it. But the user can gain information about the pigment via the optical properties of the interference – the colour shift when changing from steep to flat illumination.

A new method demonstrates differences between white and colour interference pigments as well as differences between interference and aluminium pigments. White interference and aluminium pigments reflect at a higher level when illuminated from a flatter angle. However, there is no additional colour shift as with colour interference pigments. This colour shift combined with the higher reflections at a flatter illumination is a typical feature of colour interference pigments and can be used for identification and characterisation.

COMBINED GEOMETRY OFFERS INSIGHTS

Interference pigments react when there is a change in the angle of the incident light with a colour shift: If the illumination is flattened to the same extent as the angle to the gloss (aspecular), its colour shifts to shorter wavelengths. This shift is an essential feature of the colour interference pigments.

Figure 1: Selection of geometries (illumination and observation) to define the interference line.

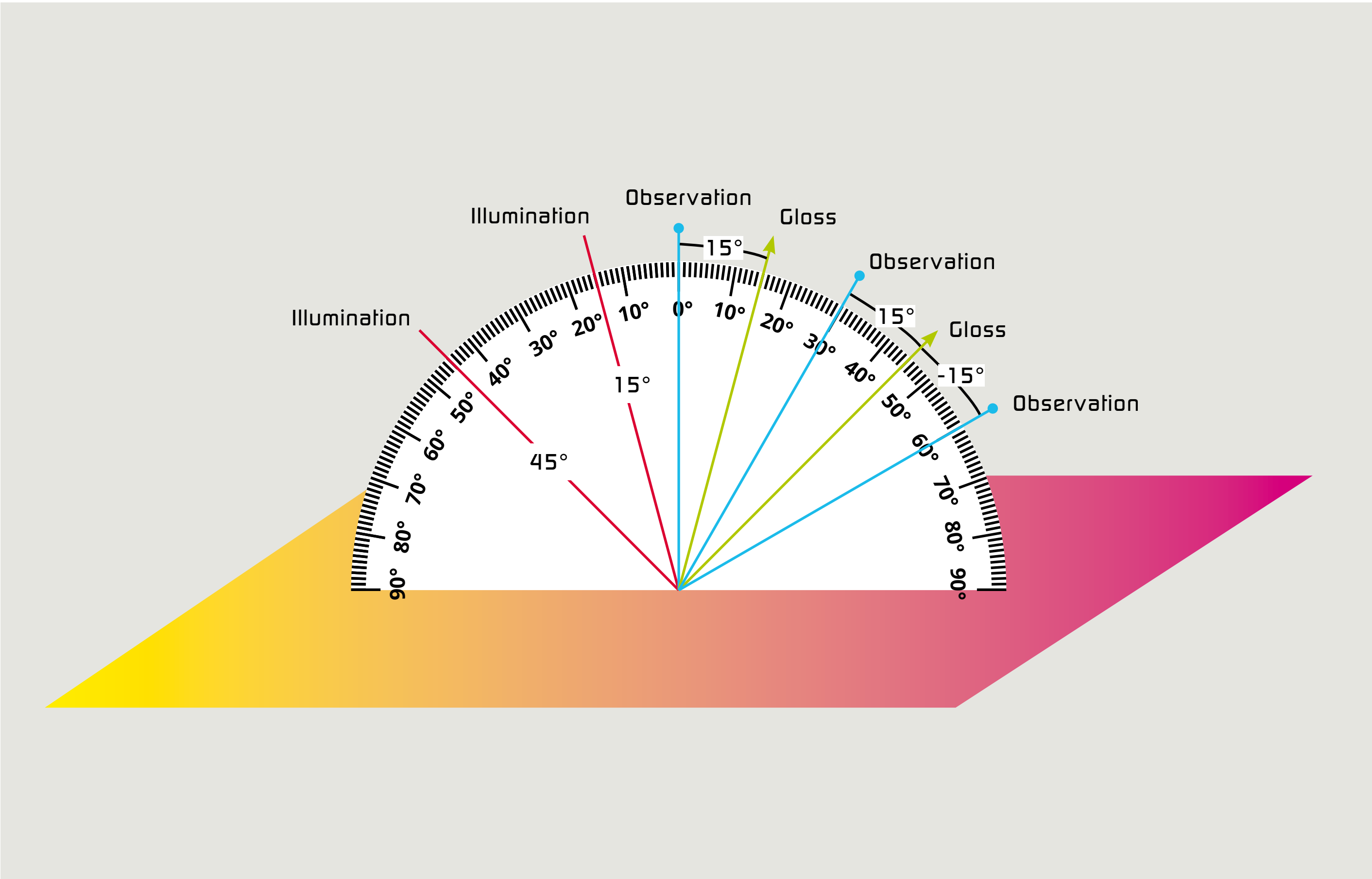
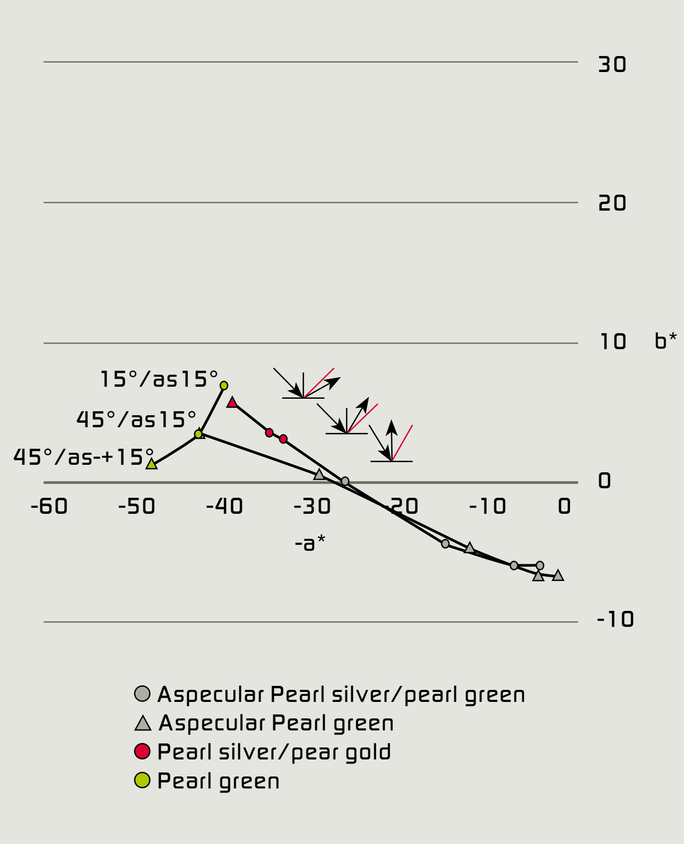


Figure 2: Two different formulations show different reactions of the interference lines. Both aspecular lines are similar.



Typically, interference pigments, but also aluminium pigments or mixtures of both pigments can be described via the combination of the interference and the aspecular line. The interference line is the connecting line of a*b*-values for steep, classic and flat illumination. Usually the measurements are used for illuminations of 15° and 45° with a differential angle to the gloss of 15° in each case.
Instead of the flat illumination with the same differential angle, the geometry 45°/as-15° (45° illumination/aspecular -15°) can be used due to the light reversal. If the optical path is reversed with this geometry, this geometry corresponds to a geometry of 60°/as15°, i.e. a flat illumination with the same differential angle of 15° (see *Figure 1*). Measurements at a fixed illumination angle of 45° form the aspecular line. Here the manufacturers of the measuring instruments offer aspecular angles (aspecular) of 15°, 25°, 45°, 75° and 110°. The first three aspecular angles are important to characterise interference pigments. If you combine both lines, you get a typical anchor shape with colour interference pigments. In this case, the interference line with the flat illumination always bends in an anti-clockwise direction. This typical feature is not found with white interference pigments or aluminium pigments. For them, the interference line is practically an extension of the aspecular line, as both white interference pigments and aluminium pigments reflect more but show no colour shift when illuminated from a flatter angle (*Figure 2*).

INTERFERENCE LINE REFLECTS THE OPTICAL PROPERTIES

When comparing different interference pigments and their blends with absorbing pigments, it is noticeable that the interference line remains almost the same. If a blue interference pigment was mixed with a red-absorbing pigment, you can see the blue interference colour near gloss. If it were not to be observed, it would make no sense

Figure 3: Typical interference lines of blends with white and colour interference pigments.

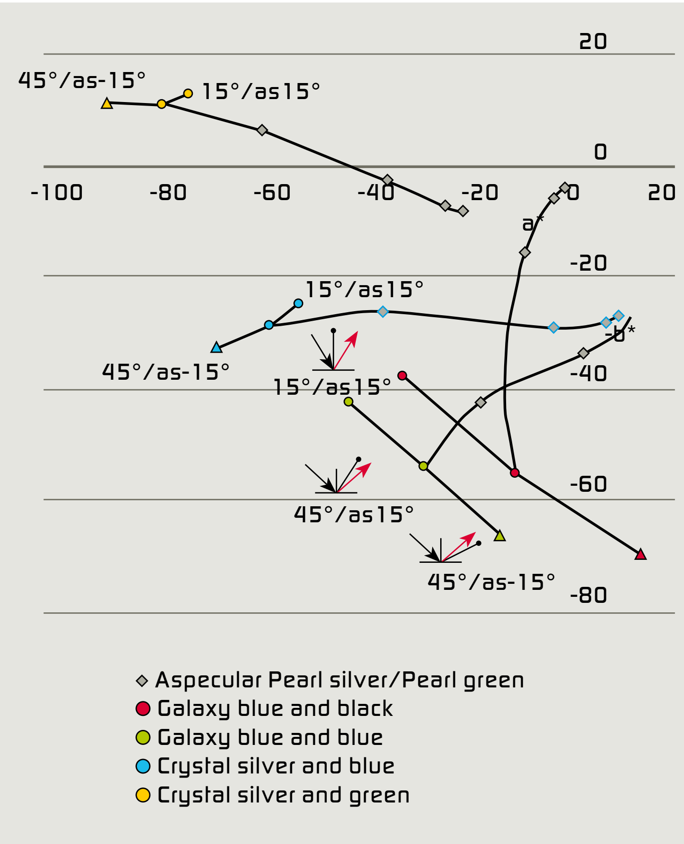
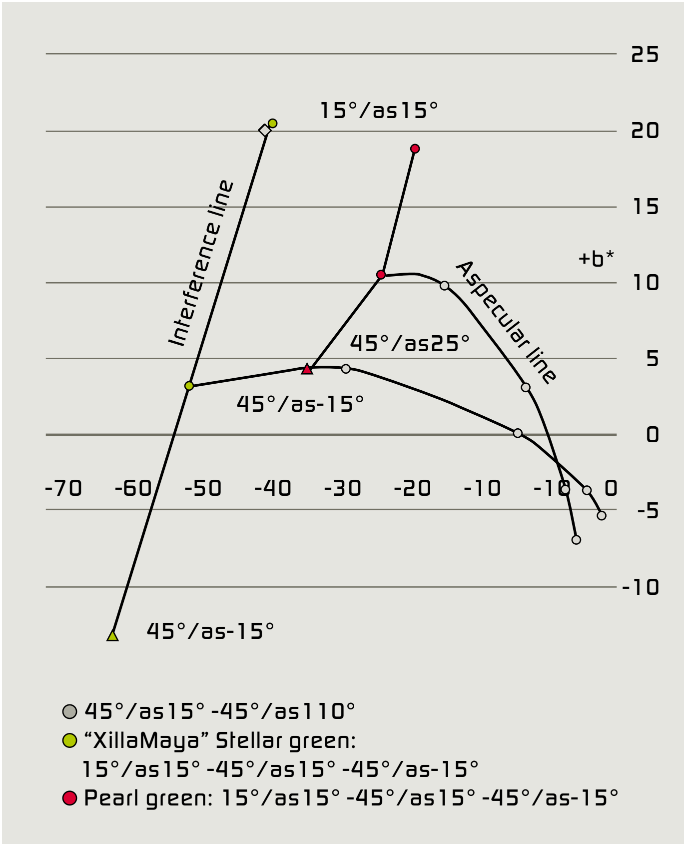


Figure 4: The chart shows the colour shift of different green pigments.



to mix the blue interference pigment with a red-absorbing pigment. Further away from the gloss, the colour influence of the absorbing pigment predominates. Even when changing the medium, whose refractive index has a definite influence on the resulting colour, the basic properties of an interference pigment are retained. Thus, a blue interference pigment does not turn green when incorporated in plastic rather than coatings (*Figure 3*).
Interference pigments are unique and have their own optical properties, making it possible to distinguish even pigments that are structurally identical. It is helpful to understand these properties, especially with adjustments of unknown blends. Here, the interference line plays a major role: It reflects the optical properties of each interference pigment. It is all about the form of this interference line, its absolute position in the a*b* chart plays a secondary role.
Compared with the interference line of the masstone, coloured and aluminium pigments shift its position. The aspecular line is also positioned accordingly with its initial value at 45°/as15°. In order to characterise and identify the interference pigment, evaluation is independent of the colour location. The relative representation of the measured values offers the advantage of being able to more accurately determine the optical properties of an interference pigment, also in blends. An interference pigment is best described by the interference line (15°/as15° – 45°/as15° – 45°/as-15°) and the aspecular line (45°/as15° – 45°/as110°), see *Figure 4*.

NARROWING DOWN THE RANGE FOR EASIER IDENTIFICATION

Here is a method described to characterise interference pigments in more detail. The bases are many panels of different

Figure 5: The measured value of the geometry 45 /as15° is selected as the zero point of a coordinate system and is used to calculate the parameters s1 to s6.

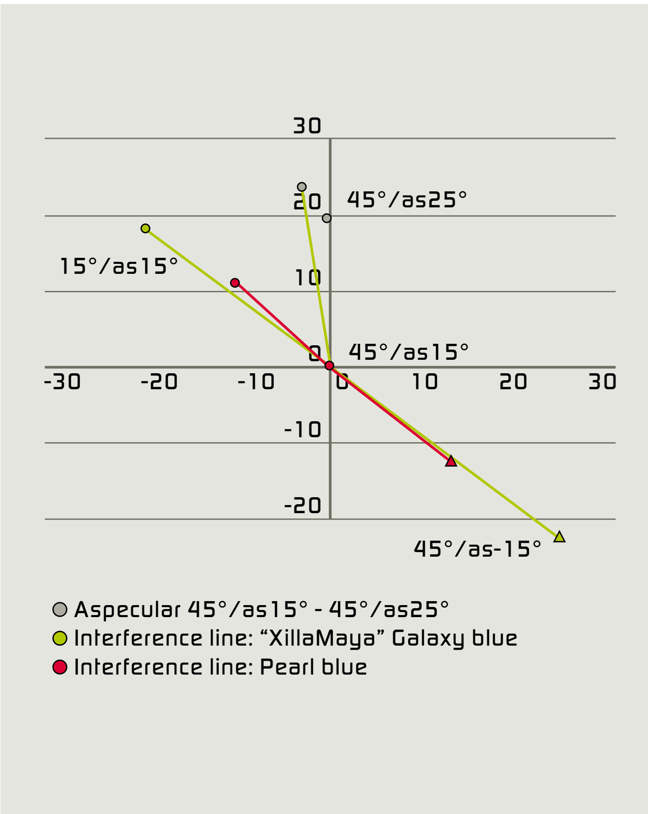


Figure 6: Typical presentation of two green interference pigments. They differ strongly in the length of the interference line and the angle between their parts.

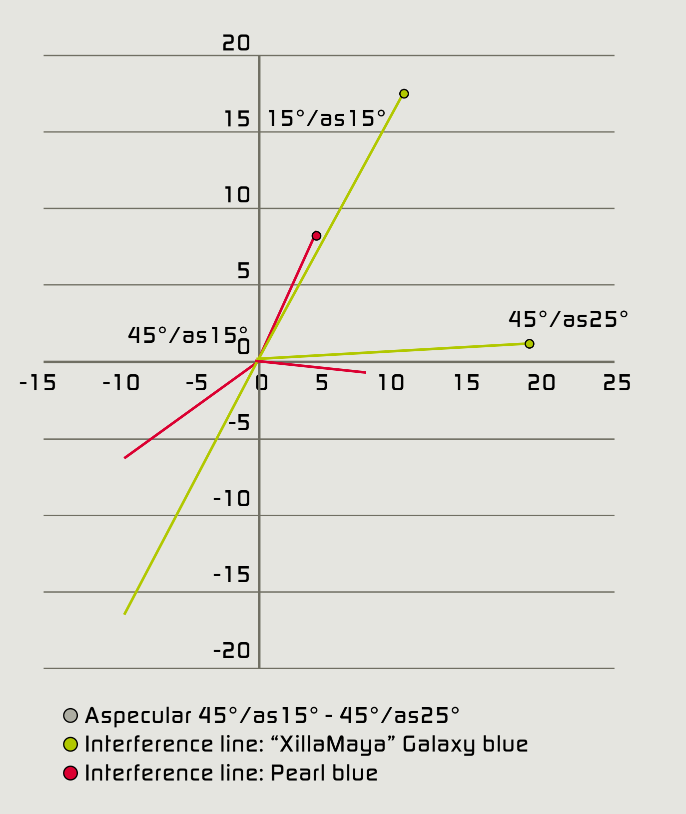
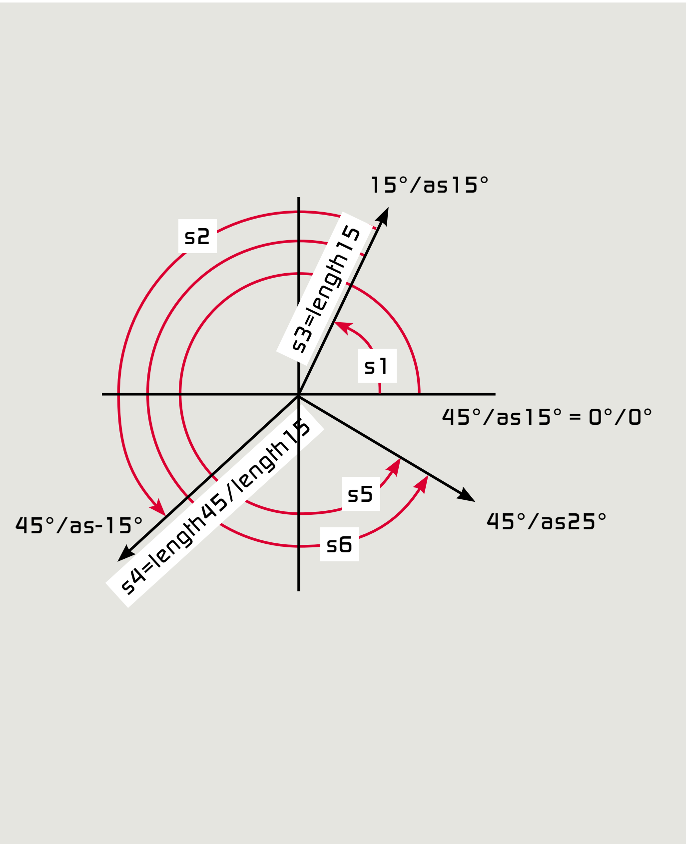


Figure 7: The values s1 to s6 are calculated by the angles between the sub-lines and their lengths.



types and blends, which were measured with the mentioned geometries. The measured values in each case produced the interference line (measuring geometries 15°/as15° – 45°/as15° – 45°/as-15°) and the aspecular line (measuring geometries 45°/as15° – 45°/as25° – 45°/as45°). The additional geometries were not used because they have no direct influence on the interference.

The combination of interference and aspecular line represents each individual interference pigment. There are six defined parameters that describe the position and the course of the lines: First, a coordinate system with x- and y-axis is placed in the a*b* value for the geometry 45°/as15° (45° illumination/aspecular=off gloss 15°). This geometry is contained in both lines and is thus a common starting point. With this transformation, the different parts and angles of the two lines now get a unique assignment, reflected in the six parameters (*Figures 5* and *6*).

Existing, known patterns help to determine ranges for the parameters, which can then be used to query a database. These queries take place one after the other, which means that the selection is increasingly concentrated on the sought-after interference pigment. It is also useful to create sample blends with interference and aluminium pigments in order to collect appropriate measurement data. The calculation and definition of the parameters are based on the following descriptions (*Figure 7*).

› Parameter s1:

The part of the interference line from the steep to the classical illumination (15°/as15° and 45°/as15°) forms a certain angle to the x-axis. Green interference pigments have a smaller angle than, for example, red interference pigments. The angle is therefore dependent on the reflection colour and is thus the first important indication of an interference pigment.

› Parameter s2:

The second parameter also refers to the interference line. It describes the angle between both parts of the interference line. It does not always have to be 180°, it can deviate from this value. The parts are formed by the portions of the interference line of 15°/as15° to 45°/as15° and 45°/as15° to 45°/as-15°.

› Parameter s3:

This parameter reflects the length of the part from 15°/as15° to 45°/as15°.

› Parameter s4:

Parameter 4 indicates the ratio of both parts from 15°/as15° to 45°/as15° and from 45°/as15° to 45°/as15°. The ratio is an important component than the length of the second leg. In combination with parameter 3, this helps to determine the length of the interference line.

- Parameter s5:

For interference pigments and their blends, the aspecular line runs approximately in the direction of the achromatic point. Therefore, the angle between the x-axis and the line segment 45° /as15° to 45°/as25° is used for the characterisation.
In the case of green interference pigments, the angle is very large (between 270° and 360°), while for red interference pigments it is significantly smaller (180° to 270°).

- Parameter s6:

The sixth parameter refers to the angle between the first part of the interference line and the described part of the aspecular line. It corresponds to the difference between parameter s5 and parameter s1.
The terms s1 to s6 are arbitrary. The angles are converted into values between 0 and 1000 for practical reasons. All experiments have shown that even with similar pigments a differentiation based on these parameters is possible (*Table 1*).

EXPERIMENTAL

To test this method, I used a database of different interference pigments and their blends. I first selected some interference pigments and determined their s1 to s6 values from the database. Using this selection, I set a range for each parameter. The first test was carried out using a commercial green/purple pigment ("ChromaFlair 190"), whose colour gradient from yellow-orange runs with flat illumination over red, violet and blue to green with steep illumination. All of these green/purple panels could be found right away in the database. Due to its chroma, this pigment can easily be identified as a masstone. The same manufacturer offers similar pigments, which made differentiation appropriate using this method.

PEARL RED

For the second experiment, I chose pearl red from a manufacturer that appears in the database as a masstone and in blends. In the first query with s1, I found 71 patterns, which included different colour interference pigments in addition to pearl red and its blends. Further query with s2 reduced the result to 31 panels, again with some other interference pigments. The third query with s3 yielded 19 hits of pearl red and less similar interference pigments. And with the 4th query with s4, 16 patterns remained, which was reduced to 12 in the next query s5. These 12 patterns corresponded exactly to the manufacturer's pearlescent pigments in the database.
I repeated the process with pearl red from another manufacturer. The query with its parameters provides only this pearl red in the database.

PEARL BLUE

The query with the first parameter s1 resulted in 77 hits for pearl blue from different manufacturers as well as similar pigments. The second query reduced these hits to 26 and the fifth query found all 12 blue interference pigments of this manufacturer.
The process was repeated with a different manufacturer's pearl blue pigment. Again, the query led exactly to this pigment.

"The introduction of this method is relatively unproblematic."

Werner Rudolf Cramer
Consultant
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3 questions to Werner Rudolf Cramer

Which method has been used to identify interference pigments so far? How much time has been saved? *The common methods are rather reactive by using existing coating formulations. Also, the current measuring instruments are only partially suitable for identification, because the corresponding geometries are not offered. An active method speeds identification by using the optical properties of the pigments.*

How complex is it to integrate the new method into existing processes? *If one uses existing databases, the introduction of this method is relatively unproblematic. For this purpose, as with all methods, calibrations of the pigments are carried out, which are the basis for determining the optical properties. These refer not only to coloured interference pigments, but also to white and aluminum pigments.*

For which field of application is the new method best suited? *The car paint industry has the greatest benefit in identifying interference pigments faster and more clearly in new or unknown panels. And that applies to both the refining and OEM sectors. This method can also be used during production or in the pigment input control. At least, the advantages lead to better performances.*

STELLAR GREEN

Based on the measured interference line (15°/as15° - 45°/as15° - 45°/as-15°), it is usually possible to read the colour area of an interference pigment. Its position indicates appropriate optical processes. More difficult is a differentiation of similar colour interference pigments. I selected a Pearl green and a Stellar green.

Stellar green has a much wider range of interference than Pearl green, even compared with similar pigments. At low concentrations, however, this span can be shorter and comparable to that of Pearl green. However, they still differ by the arrangement of the interference and aspecular lines, which is recognisable in the calculated parameters.

These parameters clearly show the differences between a stellar green and a pearl green, which makes it possible to differentiate both pigments. Experiments with mixtures of interference pigments with absorbing coloured pigments lead to the same results.

NEW METHOD SIMPLIFIES COLOUR REPRODUCTION

The described method identifies interference pigments faster and more accurately than before. It is a simple tool, especially for refinishing applications. In this method, various panels with a known interference pigment are prepared and measured as calibration standards. The various parameters are calculated from the measured values and used for the data query. The parameters of different panels with the same interference pigment are set as the query range, and this range can be set to be larger or smaller as needed for the query.

The colour measurements of interference pigments are not limited to colours or colour changes, but also provide additional information to uniquely describe and identify the pigments. This results in assistance to reproduce colours, for example, in refinishing operations and OEM car coatings.