闪烁与变幻：两种感知现象

Sparkle and Flop — Two Perceptions

效果颜料在汽车涂料通常以铝或干涉颜料的形式而广泛应用。这些颜料的视觉效果会随着观察角度和光照条件的变化而变化。

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尽管通过反射值的比色测量和转换为 CIELAB 值可以实现精确分析，但基于感知的参数在准确捕捉光泽度方面存在局限性。本文将探讨这些感知在实际应用中的表现，并讨论量化这些感知所面临的挑战。

在评估这两种感知现象时，需要注意的是，当目视检查一张明信片大小的样本时，上下边缘之间的视角差异为 15° 至 20°。这一范围超过了仪器测量中使用的前两个近似光泽反光角——15° 和 25°。

视觉评估与仪器评估之间的另一个区别在于观察区域：视觉评估会全面检查整个样本，而仪器测量则仅限于一个小区域。为了解决这一差异，我们开发了 GonioViewer，它能够实现与仪器测量相同面积的视觉观察（参见 CCJ 2024 年 11 月刊）。这种差异在比较视觉上的「闪光」和「暗点」印象与相应的仪器测量结果时尤为明显。

闪光

2000 年，德国制造商默克公司推出了一种新的白色干涉颜料，汽车设计师对这种所谓的「白色金属」颜料表现出极大的兴趣。然而，这并不是真正的金属颜料，而是一种基于氧化铝（即铝的氧化物）的标准透明干涉颜料。与其它透明干涉颜料一样，它表面涂覆了二氧化钛或氧化铁。当时，便携式多角度仪器仅在五年前问世，人们对干涉颜料的比色评估知识还很有限。因此，很难将这种新颜料与现有的干涉颜料区分开来。

这种颜料展现了一种被称为「闪光」的现象——一种视觉效果，类似于在波光粼粼的水面上看到的舞动的光影，这是由单个颜料颗粒引起的。与中国的坤彩公司生产的类似干涉颜料 XillaMaya 水晶银不同，默克公司的白色颜料同

Effect pigments are widely used in automotive coatings, typically in the form of aluminium or interference pigments. These pigments change their visual appearance depending on the angles of illumination and observation. While colourimetric measurements of reflection values and conversions to CIELAB values allow for precise analysis, such perception-based parameters have limitations in accurately capturing sparkle and flop. This article presents these perceptions in real-world applications and discusses the challenges in their quantification.

When evaluating both perception phenomena, it should be noted that when visually inspecting a sample sheet (postcard-sized), there is a 15° to 20° difference in viewing angles between the top and bottom edges. This range exceeds that of the first two near-gloss aspecular angles — 15° and 25° — used in instrumental measurement.

Another difference between visual and instrumental assessment lies in the area observed: visual assessment involves evaluating the entire sample sheet, while instrumental measurement is limited to a small spot. To resolve this discrepancy, we developed the GonioViewer, which enables visual observation over an area equivalent to that measured by instruments (see also CCJ November 2024). This difference is also evident when comparing the visual impressions of sparkle and flop with their corresponding instrumental measurements.

Sparkle

When a new white interference pigment was introduced by the German manufacturer Merck in 2000, car designers were enthusiastic about the so-called "white metallic" pigment. However, it was not a true metallic pigment, but rather a standard transparent interference pigment based on alumina (aluminium oxide). Like other transparent interference

时含有绿色和红色颜料，使得红绿相间的「闪光」效果尤为明显。

2008 年，美国材料与试验协会（ASTM）制定了 E2539 标准方法，用于测量干扰色。该标准规定使用第二个光源，并在光泽度角度之外增加额外的测量角度。大约同一时期，毕克（BYK）公司推出了新的多角度仪器 BYKmac，该仪器在 45° 和六个其它角度进行照明，以从光泽度角度获取数据。此外，测试样品还在三个角度（15°、–45° 和 –75°）下被照射，以在正常位置捕捉黑白图像。BYK 随后根据这些图像计算出闪光参数。

爱色丽（X-Rite）MA-T12 以与三恩时（3nh）MS3012 类似的原理计算闪光参数，采用在 15° 角度处采集的测量值。这两种仪器均基于光反转原理工作，即照明和检测过程是相反的。

由于闪点不是物理量，没有明确的单位，所以最初的热情已经消退。所获得的值仅适用于特定的测试样品，不能推广。

多种因素会影响同一颜料的光泽度测量值。现代汽车漆通常由含有颜料的底漆和保护这一层的清漆组成。清漆与硬化剂和稀释剂混合，以准备喷涂——这一过程既适用于最初的生产，也适用于翻新应用。

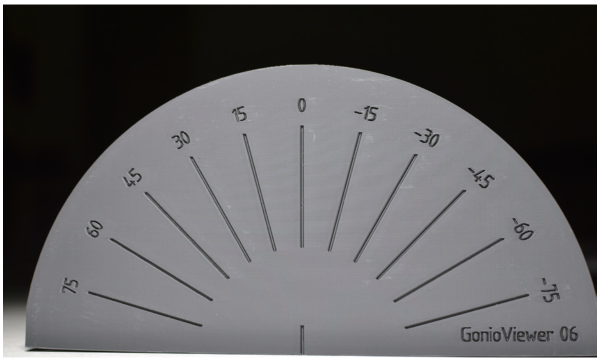

图1：GonioViewer 06在法线的两侧使用5个照明角度；沿法线进行观察。
Figure 1: The GonioViewer 06 uses five illumination angles on both sides of the normal; observations are made along the normal.

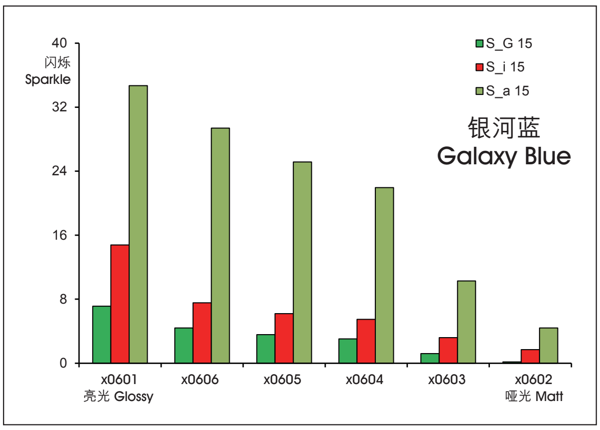

图2：底漆中使用相同的干扰颜料，而透明涂层不同——光泽度从亮光到哑光不等。
Figure 2: The same interference pigment in the base coat with different clear coats—sparkle values vary from glossy to matte.

pigments, it was coated with titanium dioxide or iron oxide. At that time, the first portable multi-angle instrument had only been introduced five years earlier, and knowledge of the colourimetric evaluation of interference pigments was still limited. As a result, it was difficult to distinguish this new pigment from existing interference pigments.

This pigment exhibited a phenomenon known as sparkle — a visual effect resembling dancing light reflections on a restless water surface, caused by individual pigment particles. Unlike similar interference pigments such as XillaMaya Crystal Silver from the Chinese manufacturer Kuncai, Merck's white pigment comprised both green and red pigments, making the interplay of red and green sparkle clearly visible.

In 2008, the ASTM (American Society for Testing and Materials) established standard method E2539 for measuring interference pigments. This standard specified the use of a second light source and additional measurement angles apart from the gloss angle. Around the same time, BYK Gardner released the new multi-angle instrument BYKmac, which featured illumination at 45° and six measurement angles from the gloss angle. Additionally, the test sample was illuminated at three angles (15°, -45°, and -75°) to capture black and white images with a camera in the normal. BYK then calculated sparkle parameters from these images.

The X-Rite MA-T12 calculates sparkle parameters in a manner similar to the 3nh MS3012, using measurement values taken at the 15° angle. Both instruments operate on the principle of light reversal, meaning illumination and detection are reversed.

Since sparkle is not a physical quantity and has no defined units, the initial enthusiasm has waned. The value obtained applies only to the specific sample tested and cannot be generalised.

Multiple factors influence the sparkle values measured for the same pigment. Modern automotive paints typically comprise a base coat containing the pigments and a clear coat that protects this layer. The clear coat is mixed with hardener and thinner to prepare it for spraying — a process used in both original production and refinishing applications.

Example 1: Same base coat with different matte clear coats

First, Xirallic Galaxy Blue was combined with two absorbent blue colour pigments and a black pigment. This base coat was then applied to six postcard-sized metal sheets. Matte and semi-matte clear coats from the PPG paint range were selected and blended according to product specifications to achieve a matte gradation. These gradations were subsequently applied to the sample sheets.

The sheets were sorted by degree of matting and catalogued in the tables and charts (x0601–x0606 … -x0602). Refer to the gloss values in **Table 1**. In **Figure 2**, differences are observed in S_G15 (sparkle grade), S_a15 (sparkle area at 15°), and S_i15 (sparkle intensity at 15°), despite all sample sheets sharing the same base coat.

Example 2: Same base coat, clear coat with different hardeners and thinners

Seven sample panels were sprayed using the same base coat, formulated to match the BMW colour Frozen Blue. The

表1：在含有银河蓝色干扰颜料的相同底漆上施加清漆。
Table 1: Clear coats applied to the same base coat containing the Galaxy Blue interference pigment.

	半光 Semi-gloss (D8115) (%)	哑光 Matte (D8117) (%)
x0601 银河蓝 Galaxy Blue + CC (亮光 Gloss)	0	0°
x0606 银河蓝 Galaxy Blue + FC05	0	100
x0605 银河蓝 Galaxy Blue + FC05	30	70
x0604 银河蓝 Galaxy Blue + FC05	50	50
x0603 银河蓝 Galaxy Blue + FC05	70	30
x0602 银河蓝 Galaxy Blue + FC05	100	0

示例 1：相同的底漆，不同的哑光清漆

首先，将 Xirallic 银河蓝与两种吸水性蓝色颜料及黑色颜料混合。接着，将这种底漆涂覆在六张明信片大小的金属板上。根据产品规格，从 PPG 涂料系列中选择了哑光和半哑光透明涂层，并进行了混合，以实现哑光渐变效果。随后，这些渐变效果被应用到了样品板上。

这些纸张按照遮光程度进行了分类，并在表格和图表（x0601 至 x0606... 至 x0602）中进行了编目。请参见**表 1** 中的光泽值。**图 2** 显示，尽管所有样本纸张都使用了相同的底涂层，但在 S_G15（闪光等级）、S_a15（15° 处的闪光面积）和 S_i15（15° 处的闪光强度）方面存在差异。

示例 2：相同的底漆，透明涂层使用不同的硬化剂和稀释剂

七个样本面板使用了与宝马冰蓝色相匹配的底漆进行喷涂。**图 3** 列出了哑光和透明涂层的组合，以及相应的硬化剂和稀释剂添加量。**图 4** 和**图 5** 展示了不同硬化剂和稀释剂对光泽参数的影响。

虽然所有样品的底漆保持一致，但固化剂和稀释剂的变化影响了闪光参数，证明了它们对最终外观的影响。

示例 3：不同的测量方向

将含有 Xirallic 银河蓝、铝和彩色颜料的底漆涂覆于样品片上，并用透明涂层密封。随后，测量仪器旋转 90° 以评

table (**Figure 3**) outlines the combinations of matte and clear coats along with the respective additions of hardener and thinner. The charts (**Figures 4 and 5**) illustrate how the sparkle parameters vary depending on the hardener and thinner used.

Although the base coat remained consistent across all samples, the sparkle parameters were affected by the variations in hardener and thinner, demonstrating their influence on the final appearance.

Example 3: Different measurement directions

A base coat containing Xirallic Galaxy Blue, aluminium, and coloured pigment was applied to a sample sheet and sealed with a clear coat. The measuring instrument was then rotated by 90° to evaluate the sparkle effect.

The chart illustrates the dependence of sparkle measurements on instrument positioning. Since the BYK device illuminates from both sides of the normal (15°, -45°, and -75°), precise alignment is essential. Currently, no known studies have assessed whether this angle configuration is adequate or optimal. A more sensible approach, in our view, would involve illuminations at 15°, 30°, and 60° (see also CCJ November 2024).

Example 4: Sparkle observed in solids without effect pigments

When solids containing only colour pigments are measured using the BYKmac or X-Rite MA-T12, sparkle parameters are still generated. Although the X-Rite MA-T12 reports different

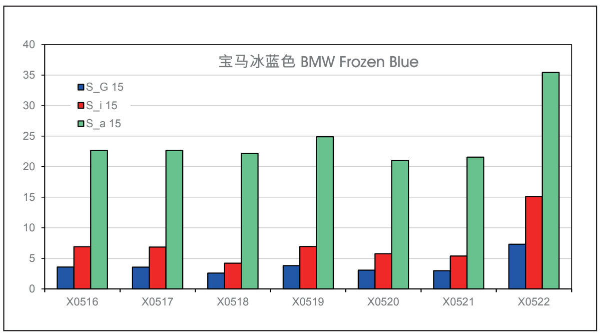

图3：相同的底漆，不同的清漆；清漆中的固化剂和稀释剂会影响闪亮值。
Figure 3: The same base coat with different clear coats; hardeners and thinners in the clear coat influence the sparkle values.

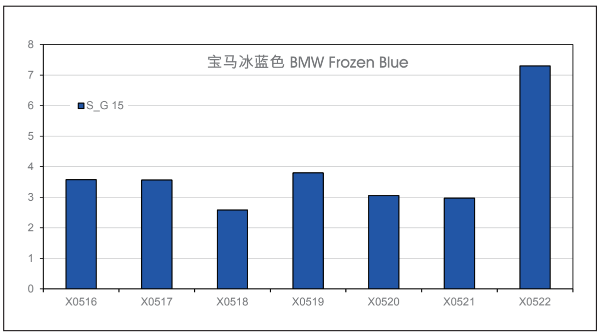

图4：15°时的闪点等级Sg受清漆成分的影响。
Figure 4: Sparkle grade Sg at 15° is influenced by the composition of the clear coat.

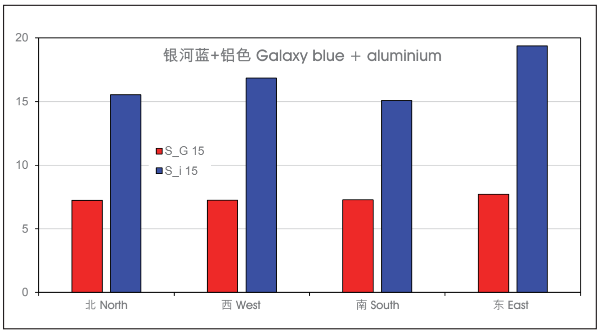

图5：旋转测量装置90°，改变同一样板上的闪光值。
Figure 5: Rotating the measuring device by 90° changes the sparkle values on the same panel.

估其闪耀效果。

图表展示了仪器位置对闪光测量值的影响。由于 BYK 设备从正前方（15°、–45° 和 –75°）两侧进行照明，因此精确对齐十分重要。目前，尚无研究评估这种角度配置是否足够或最优。我们认为，更合理的做法是在 15°、30° 和 60° 处进行照明（参见 CCJ 2024 年 11 月刊）。

示例 4：在无效应颜料的固体中观察到的闪亮

当使用 BYKmac 或 X-Rite MA-T12 测量仅含颜料的固体时，仍会生成闪光参数。尽管 X-Rite MA-T12 报告了不同的闪光等级值，但仍有可测量的数值存在。原则上，在这种情况下不应报告任何闪光或粗糙度的值。

BYKmac 的结果表明，当引入白色颜料时，与闪光相关的参数显著下降。

示例 5：同样的闪光，不同的颜色

所确定的闪亮值仅适用于特定样品面板及其着色。这

values for sparkle grades, measurable values are nonetheless present. In principle, no values should be reported for either sparkle or coarseness in such cases.

Results from the BYKmac show a significant drop in sparkle-related parameters when a white pigment is introduced.

Example 5: Same sparkle, different colour

The sparkle values determined apply only to the specific sample panel and its pigmentation. These values do not correspond to a particular pigment and therefore cannot be transferred to other pigment formulations, even if they contain the same effect pigment.

Upon querying our database, we identified mixtures with identical sparkle parameters but differing pigment compositions. One example includes Xirallic Galaxy Blue combined with aluminium — one sample contained the solid_2 colour pigment, while the other did not.

In a second example, Pearlblue with aluminium and solid_2 was compared to Galaxy Blue with solid_2. Both exhibited the same sparkle grade (Sg) and similar values for sparkle area (Sa) and sparkle intensity (Si). These findings highlight the limited informative value of sparkle parameters when used in isolation.

Sparkle is a phenomenon of perception, not a physical quantity. It depends on numerous factors, as illustrated in the preceding examples. For nuanceurs at paint manufacturers — those responsible for reproducing car colours — the challenge lies in the fact that sparkle parameters increase when the concentration of Crystal Silver is reduced. In contrast, the sparkle of aluminium pigments increases as their concentration increases. In other words, they behave in opposite ways.

Automotive colours typically contain four to eight pigments, and understanding their interactions is critical. This complexity becomes especially challenging when attempting to reproduce a colour that includes Crystal Silver.

Originally, sparkle measurement was introduced solely for Xirallic Crystal Silver. However, users have since extended this measurement approach to all effect pigment paints,

表2：无效果颜料的固体也可显示闪光值（闪光等级）。
Table 2: Solids without effect pigments can also display sparkle values (sparkle grade).

控制板 Panel	日期 Date	途径 Channel	版本 Version	粗糙度 Coarseness	闪光等级（亮度/对比度）Sparkle grade (brightness all contrast)	闪光等级（倾斜度）Sparkle grade (skewness)	闪光等级（点）Sparkle grade (spot)	颜色参数 Colour parame	基于颜色的闪光等级（亮度/对比度）Colour based sparkle grade (brightness all contrast)	基于颜色的闪光等级（倾斜度）Colour based sparkle grade (skewness)	基于颜色的闪光等级（点）Colour based sparkle grade (spot)	闪光等级（所有通道点）Sparkle grade (spot all channels)
green 3.1	2024-12-11	r15as15	Version 5.1	0.91	1.67	2.10	3.32	17.62	2.05	2.44	3.44	3.51
yellow	2024-12-11	r15as15	Version 5.1	0.42	0.04	1.22	1.04	4.33	0.06	0.81	0.72	1.22
red	2024-12-11	r15as15	Version 5.1	1.00	1.62	1.54	2.85	2.73	0.79	0.76	1.21	2.46
green 10:1	2024-12-11	r15as15	Version 5.1	0.94	1.29	2.03	2.69	15.31	1.58	2.22	2.74	2.76
white	2024-12-11	r15as15	Version 5.1	0.34	0.06	2.14	1.14	8.24	0.11	1.69	1.05	1.20
light grey	2024-12-11	r15as15	Version 5.1	0.19	0.14	1.94	1.00	7.67	0.21	1.52	0.92	1.17
dark grey	2024-12-11	r15as15	Version 5.1	0.42	0.86	2.09	2.56	15.48	1.17	2.28	2.65	2.51
black	2024-12-11	r15as15	Version 5.1	2.15	7.06	1.60	7.72	15.89	5.75	1.89	6.15	7.74
x1185	2024-12-11	r15as15	Version 5.1	0.25	0.00	0.05	0.00	1.97	0.00	0.05	0.00	0.39

表3：在冷蓝色底漆上使用不同固化剂和稀释剂时的清漆变化。
Table 3: Variations of clear coats with different hardeners and thinners applied to Frozen Blue base coats.

控制板 Panel	哑光：亮光 Matt: gloss	固化剂 Hardener	稀释剂 Thinner
x0516	70:30	30 – 40	长效 Long
x0517	75:25	30 – 40	长效 Long
x0518	80:20	30 – 40	长效 Long
x0519	75:25	30 – 40	特快 Express
x0520	70:30	10 – 20	长效 Long
x0521	75:25	10 – 20	特快 Express
x0522	亮光 Gloss	30 – 40	长效 Long

91226	15.04.03	55-Xirallic 银河蓝 galaxy blue	10	0.27	Solid_2	90	2.38			
91226	15.04.03	55-Xirallic 银河蓝 galaxy blue	20	0.51	55-silver	20	0.56	Solid_2	60	
控制板 Panel	变幻 Flop	S_G 15	S_i 15	S_a 15						
91226	9.74	6.58	20.10	22.14						
91253	23.09	6.58	13.56	32.76						

91040	26.02.03	55- 珍珠蓝 Pearl blue	30	0.81	55-silver	10	0.28	Solid_2	60	1.59
91236	15.04.03	55-Xirallic 银河蓝 galaxy blue	98	2.65	Solid_2	2	0.05			
控制板 Panel	变幻 Flop	S_G 15	S_i 15	S_a 15						
91040	22.74	6.97	14.99	32.84						
91236	19.00	6.97	15.81	31.21						

图6：不同的色素可产生相同的闪光值。
Figure 6: Different pigmentations can produce the same sparkle values.

些值并不对应特定的颜料，因此即使它们包含相同的效果颜料，也不能转移到其它颜料配方中。

在查询我们的数据库后，我们发现了一些具有相同闪光参数但颜料成分不同的混合物。例如，Xirallic 银河蓝与铝的组合——其中一个样品含有 solid_2 色颜料，而另一个则没有。

在第二个例子中，珍珠蓝与铝和 solid_2 进行了对比，银河蓝与 solid_2 也进行了对比。两者都表现出相同的闪光等级（Sg）以及相似的闪光面积（Sa）和闪光强度（Si）。这些发现强调了单独使用闪光参数时其信息价值有限。

闪光是一种感知现象，而非物理量。它受多种因素影响，如前文所述。对于负责汽车颜色复制的油漆制造商中的调色师而言，挑战在于当水晶银浓度降低时，闪光参数会增加；而铝颜料的闪光则随着其浓度的增加而增强。换句话说，这两种材料的行为是相反的。

汽车颜色通常包含四到八种颜料，理解它们之间的相互作用十分重要。当尝试复制包含水晶银的色彩时，这种复杂性尤为具有挑战性。

最初，亮度测量仅用于 Xirallic 水晶银。然而，用户后来将这种方法扩展到了所有效果颜料涂料上，通常没有充分考虑这种方法是否能提供准确或有意义的结果。这里提出的问题广泛适用于所有仪器和 BRDF（双向反射分布函数）模

often without fully considering whether the methodology provides accurate or meaningful results. The concerns raised here apply broadly — to all instruments and the BRDF (Bidirectional Reflectance Distribution Function) model itself.

At the ASTM meeting in Atlanta in 2012, Wolf Moritz Cramer introduced an intriguing pixel-based calculation method. In this approach, photo pixels are transferred onto a mesh with defined distances, offering an alternative way to analyse sparkle characteristics.

Flop

Another perceptual phenomenon is flop, which refers to the difference in visual impressions observed at shallow versus steep angles relative to the gloss.

In the 1980s, interest in metallic colours surged — accompanied by increasing acceptance of cars painted in these finishes. At the time, paint manufacturers sought methods to capture and describe the effects produced by such colours. Until then, colours had typically been measured using directional lighting and observation or a spherical geometry — both of which proved inadequate for effect pigments.

To address this, DuPont developed a multi-angle device called DuPontmac for internal use in the late 1980s. The device used illumination at 45° and measured reflectance at 15°, 45°, and 110° from the gloss angle. This configuration

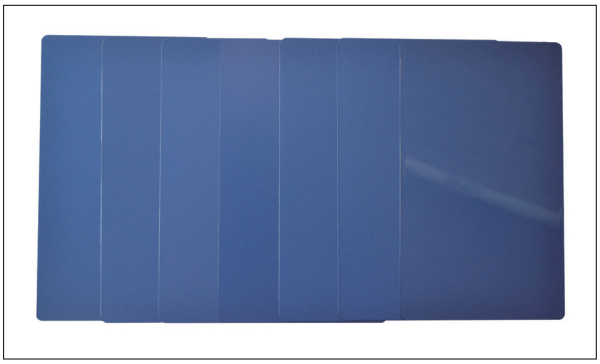

图7：白色表面的涂漆面板
Figure 7: Painted panels for a white surface

型本身。

在 2012 年亚特兰大举行的 ASTM 会议上，Wolf Moritz Cramer 介绍了一种引人注目的基于像素的计算方法。这种方法将照片像素转移到具有定义距离的网格上，为分析闪光特性提供了另一种途径。

变幻

另一种知觉现象是随角异色效应，它指的是相对于光泽度的浅角度和陡峭角度所观察到的视觉印象的差异。

20 世纪 80 年代，人们对金属色的兴趣激增，同时对这些颜色的汽车也越来越接受。当时，油漆制造商努力寻找方法来捕捉和描述这些颜色的效果。在此之前，颜色的测量通常依赖于定向照明和观察或球形几何学，但这些方法对于效果颜料来说并不充分。

为了解决这一问题，杜邦公司在 20 世纪 80 年代末开发了一种名为 DuPontmac 的多角度设备，用于内部使用。该设备采用 45° 的照明，并在 15°、45° 和 110° 的光泽角度下测量反射率。这一配置是基于对金属涂层罐和桶的视觉评估而选定的。

杜邦公司的 David H. Altman 提出了一种方法，通过测量特定角度的光泽度来计算光度。他从高光泽度（15°）的角

was chosen based on visual evaluations of metallic-coated cans and barrels.

David H. Altman of DuPont formulated a method for calculating flop using the lightness values measured at those angles. He subtracted the lightness at the low-gloss geometry (110°) from that at the high-gloss geometry (15°), and divided the result by the lightness at the intermediate angle (45°). Additional parameters were introduced to further refine the calculated flop value. At the same time, the German optics manufacturer Zeiss developed a multi-angle device that used illumination at 45° and measured reflectance at 25°, 45°, and 75° from the gloss angle. Based on the lightness values recorded at these geometries, Zeiss also introduced its own definition of a flop value.

In the late 1980s, understanding of flop indices — their underlying principles and contributing factors — was still quite limited. Today, however, flop correctors and other tools are routinely employed in laboratories to manipulate and fine-tune flop characteristics.

Example 6: Flop corrector

In the automotive paint sector, colours and effects often need to be reproduced based on a reference template. If the reproduced colour appears too light near the gloss angle, its lightness can be reduced using appropriate binders. However, it should be noted that this also increases the lightness at low-gloss geometries. As a result, the calculated flop value decreases, since the difference between the high-gloss and low-gloss lightness levels becomes smaller.

A flop corrector typically influences lightness across a wide range of viewing angles. In most cases, it reduces lightness near the gloss angle while increasing it at angles farther from the gloss.

Example 7: Carbon black

Various types of carbon black are available for automotive and industrial applications. They can generally be categorised as either bluish or brownish carbon blacks. Both types can be used as flop correctors — potentially even interchangeably — as they significantly affect lightness in glossy areas, while having a much smaller influence in non-glossy regions.

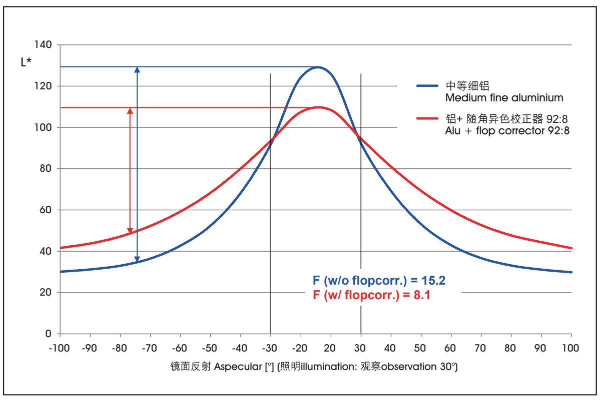

图8：一个光校正器可减少光泽附近的亮度，并增加远离光泽的角度的亮度。
Figure 8: A flop corrector reduces lightness near the gloss and increases it at angles farther from the gloss.

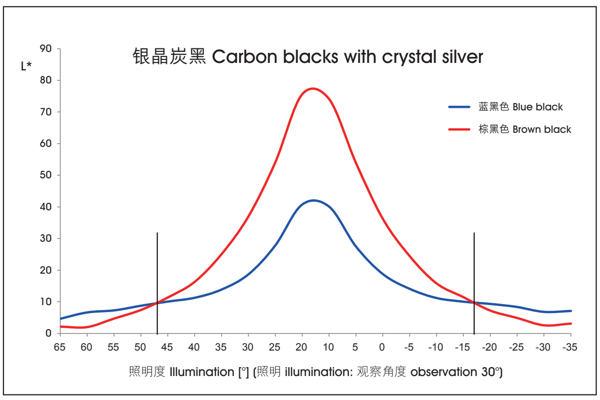

图9：替换炭黑可降低光泽度附近的亮度，而其它角度的亮度几乎不变。
Figure 9: Replacing the carbon black lowers the lightness near the gloss while leaving it nearly unchanged at other angles.

度中减去低光泽度（110°）的角度的光泽度，然后将这个结果除以中间角度（45°）的光泽度。为了进一步优化计算出的光度值，还引入了其它参数。与此同时，德国光学制造商蔡司研发了一款多角度设备，该设备采用 45° 照明，并在光泽度角度的 25°、45° 和 75° 处测量反射率。基于这些角度记录的亮度值，蔡司还提出了自己的「flop 值」定义。

在 20 世纪 80 年代末，对 flop 指数——其基本原理和影响因素——的理解仍然相当有限。然而，如今，实验室中常规使用随角异色校正器和其它工具来操纵和微调随角异射特性。

示例 6：随角异色校正器

在汽车涂料行业，颜色和效果通常需要根据参考范本来复制。如果在高光泽度角度附近颜色显得过亮，可以通过使用适当的粘合剂来降低其亮度。然而，需要注意的是，这种方法也会增加低光泽度几何形状的亮度。因此，计算出的随角异色值会减少，因为高光泽度和低光泽度之间的亮度差异变小了。

色差校正器通常会影响宽广视角范围内的亮度。在大多数情况下，它会减少光泽角度附近的亮度，同时增加远离光泽角度的亮度。

示例 7：炭黑

各种类型的炭黑可用于汽车和工业应用。它们通常可分为蓝色或棕色的炭黑。这两种类型都可以用作随角异色校正器，甚至可以互换使用，因为它们对光亮区域的亮度有显著影响，而在非光亮区域的影响要小得多。

示例 8：基材的影响

使用透明干扰颜料时，基材的颜色显著影响整体色彩效果。在本次测试中，样品面板预先喷涂了柔和的色调。随后，所有面板均涂覆了含有白色干扰颜料「水晶银」的底漆，并用透明清漆密封。当水晶银色涂覆在黄色基材上时，光泽度附近与低光泽度角度的亮度差异比其它颜色更小，从而减少掉色。

基板颜色的选择（黑色或白色）同样会影响随角异色效果。同样，基材的亮度会改变水晶银的随角异色。使用黑色基板时，这种影响尤为显著。

结语

闪亮和变幻这两种感知效果都可能受到多种因素的影响。在每种情况下，所测量的参数仅适用于特定测试样板，无法应用于具有不同颜料成分的其它样板。

例如，在汽车行业中再现效果色时，准确识别原面板中的效果颜料是成功复制的关键。闪亮值和随角异色值只能提供有限的指导，因为复制面板中感知到的效果还取决于正确识别效果颜料。

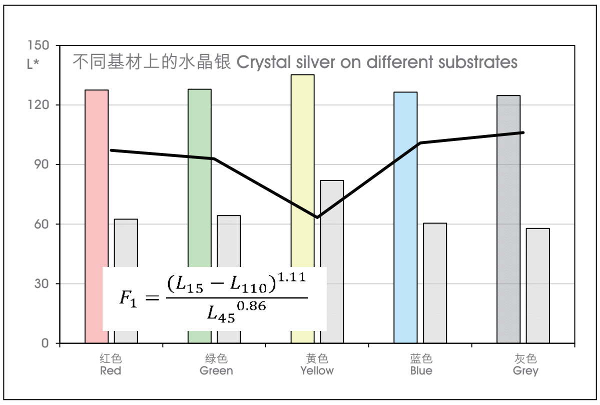

图10：在不同的背景色上施加相同的干扰颜料，表现出不同的随角异色行为。
Figure 10: The same interference pigment applied over different background colours exhibits different flop behaviours.

Example 8: Influence of the substrate

With transparent interference pigments, the colour of the substrate significantly affects the overall colour impression. In the tests presented here, sample panels were pre-sprayed with pastel colours. The same base coat — containing the white interference pigment Crystal Silver — was then applied to all panels and sealed with a clear coat. When Crystal Silver is applied over a yellow substrate, the difference between the lightness near the gloss and the lightness at low-gloss angles is smaller than with other colours, resulting in reduced flop.

The choice between a black or white substrate also influences the flop. Here again, the lightness of the substrate plays a role in modifying the flop of Crystal Silver. The effect is notably greater when using a black substrate.

Summary

Both perceptual effects — sparkle and flop — can be influenced by various factors. In each case, the measured parameters apply only to the specific panel tested and cannot be transferred to panels with different pigmentations.

For example, when reproducing an effect colour in the automotive sector, accurately identifying the effect pigments in the original panel is the most critical factor for successful replication. Sparkle and flop values offer only limited guidance, as the perceived effect in the reproduced panel also depends on correctly identifying the effect pigment.

图11：湍急水面上的光反射（闪光）
Figure 11: Light reflections on turbulent water surface (sparkle)