Color measurement of BLACK

Abstract

Already in the Stone Age, black based on charcoal was used as one of the first colors ever. The measurement and qualification of black has been a challenge since then, as it reflects hardly any light. On the one hand, special indices are needed because evaluation using L*a*b* values is only suitable to a very limited extent. On the other hand, the selection of appropriate measuring instruments with outstanding technical performance also plays an essential role. The following technical article describes how to raise quality control of deep and deepest black colors to a new level of precision and reliability.

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1 The color BLACK and its presence in our daily life

Carbon Black is a material with a long history whose production dates to the early civilizations of mankind. Initial uses can be traced back to ancient China, the early Egyptians, and India since the days before Christ. The demand for carbon black was particularly driven by the invention of the printing press in the fifteenth century. Today carbon black is found in all aspect of modern life. It is used in inkjet printer ink, as reinforcements for natural and synthetic rubber and as the active agent in electrically conductive plastics. Probably the widest and best-known application is the usage as a pigment in paints, coatings and plastics to impart a deep black color, because it has higher tinting strength compared to iron black or organic pigments. Means, not all black is the same.

2 Definition of Blackness – Jetness indices

In general, black is a color that results from the absence or complete absorption of visible light. Leading carbon black manufacturers promote carbon black pigments that absorb up to 99.98% of light. The higher the absorption coefficient of a medium, such as a black coating, the higher is the achieved blackness value (M_Y). Deep black coatings can have an undertone – bluish or brownish. A deep black color with a bluish undertone in the full tone is perceived as richer, darker and more brilliant than with a brownish undertone. Two samples with the same blackness (M_Y) and different undertone (dM) can be perceived as different blacks, whereas the sample with blue undertone will be perceived as deeper black. For this reason, black with a blue undertone is often preferred in technical applications, such as for the topcoats in the automotive industry. The hue-dependent degree of blackness is referred to as “Jetness” (Mc).

The calculation for the Blackness value M_Y is based on the Tristimulus Value Y and a 10° Observer (Fig. 1). It determines only the lightness of a sample without considering the colored undertone. As the undertone of a black color has an impact on the visual assessment, the hue-dependent degree of blackness M_Y needs to be calculated (Figure 1). The black value Mc describes higher Jetness, if there is a blue undertone and lower Jetness, if the shade is more brownish. The difference between the black value Mc and the black value MY defines the hue of a black color, the so called Undertone (dM) (Fig. 1). Undertone dM describes the amount of blue shade in case of positive values and the amount of brown shade in case of negative values (Fig. 2). Blackness (M_Y), Jetness (Mc) and Undertone (dM) are specified in international standards: ISO/DIS 18314-3 and DIN 55979.

Blackness My:

$My = 100 \log (100 / Y)$

Jetness Mc - Color depending black value

$Mc = 100*(\log(Xn / X)–\log(Zn / Z)+\log(Yn / Y))$

Undertone dM - Absolute contribution of hue

$dM = Mc – My = 100*(\log(Xn / X)–\log(Zn / Z))$

Fig. 1: Calculation of Blackness Indices

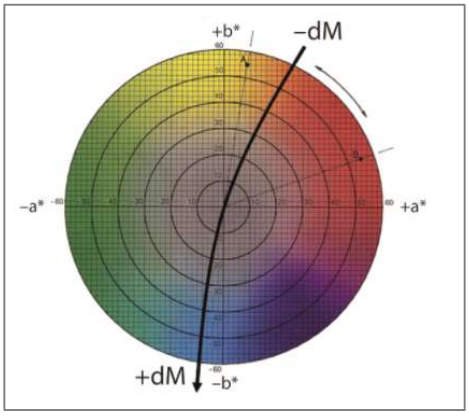

Fig. 2: Undertone dM

3 The challenge of color measurement for BLACK colors

3.1 Signal to noise ratio

It has always been the greatest challenge for a spectrophotometer to achieve repeatable and reproducible results on a black color. While a white sample reflects almost 100 percent of the light emitted by the spectrophotometer, the proportion of reflected light becomes smaller and smaller with darker colors - as increasingly larger amounts of light are absorbed by the sample. Consequently, the so-called "signal to noise ratio" changes with dark colors: The measurement signal decreases while the thermal noise, which is basically caused by electronic components, remains constant. Measurements of innovative, deepest black coatings with very low reflection takes place at a lightness value of L* < 1 (Fig. 3). This is a challenging task for a measurement instrument and pushes the technical performance of a handheld spectrophotometer to the utmost limit.

3.2 Development of the Pro models

BYK Instruments has taken up the challenge to develop a handheld as well as bench-top instrument, which measure black and describe its undertones no matter how deep black the color might be. Leading specialists from carbon black pigment manufacturers challenged us in assessing the measurement accuracy with deepest blacks as sample material. The basis for the excellent performance is the use of high-power LEDs as light source, which, thanks to the BYK-specific production control process, provide an exceptional short-term as well as long-term stability and ensure an absolutely homogeneous illumination of the measuring spot., To master the "signal to noise ratio", highest precision electronic and optical components are combined with a special calibration and operation mode for measurement of black colors: LED lamps are powered with more energy resulting in a higher light intensity and the illumination time is extended. In this so called Jetness-mode colors with low black values cannot be measured. The user is asked to remeasure the sample in the “regular” measurement mode and the so-called G-values (Grayness values) will be shown in lieu of M-values. The Jetness indices (M-values and G-values) are defined in DIN ISO 18314-3. Thus, on deep blacks with high light absorbing capabilities, the spectro2guide Pro and color2view Pro will be both able to deliver a perfectly stable signal with the highest possible accuracy.

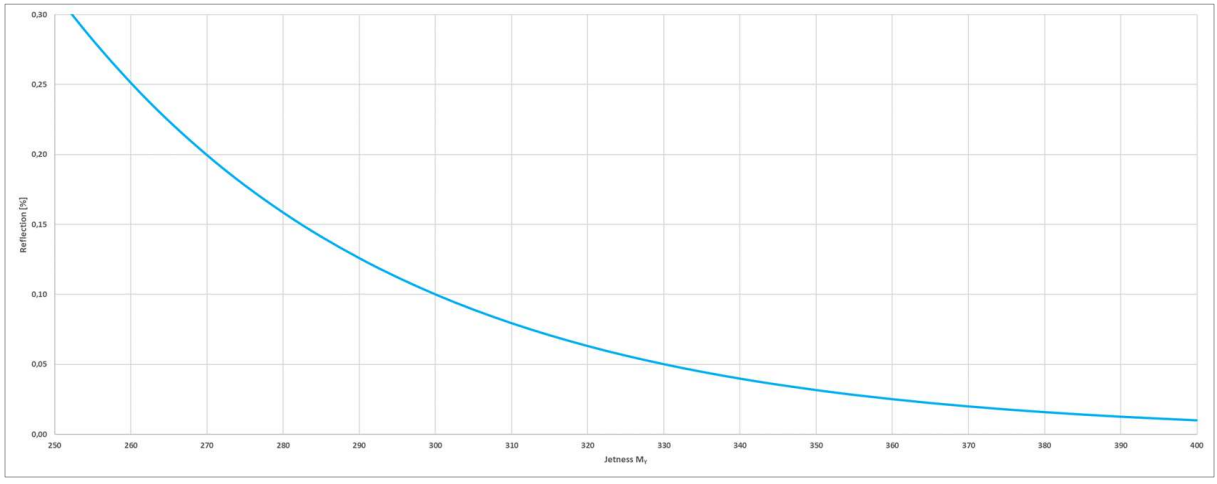

Fig. 3: Decreasing Remission with increasing M_Y

4 Color measurement of several deep BLACK colors

4.1 Samples and Sample Preparation

The spectro2guide Pro was tested on 6 samples “Test 1 - Test 6” with graduated MY and dM values. The samples are glass plates painted with high-gloss black. Deep blacks can only be measured on high-gloss and absolutely clean samples. Any contaminants or surface irregularities can have a considerable influence on the measurement results. Due to that, the sample surface must be absolutely free of scratches, fingerprints and dust before measuring. During the test, the sample surface was cleaned with distilled water and lint-free delicate task wipes before the measurement. To guarantee that the sample surface is perfectly prepared, an LED flashlight is included with the spectro2guide Pro. The lamp can be used to assess the quality of the sample surface under strong direct light. A 15 - 45-degree angle of illumination has proven to be most effective.

4.2 Visual Assessment

The visual assessment was made in the light booth byko-spectra pro with daylight D65 under a 45-degree angle. The byko-spectra pro uses a smart combination of filtered tungsten-halogen lamps and LEDs to simulate D65 resulting in the highest rendering Class A according to CIE 51.2. Due to that, the “byko-spectra pro” is ideal for color critical appraisal of solid colors and guarantees accurate color matching according to CIE illuminant D65.

The trained observer can sort the samples by their degree of blackness. The order corresponds to the naming of the samples: Sample "Test 1" is the sample with the lowest blackness value (M_Y) and sample "Test 6" is the sample with the highest blackness value (M_Y), deepest black. The samples "Test 5" and "Test 6" can hardly be separated from each other. Regarding the undertone, sample "Test 5" and "Test 6" are perceived as clearly bluish (dM). Sample "Test 1" appears to have a yellow undertone (dM). The samples "Test 2" to "Test 4" tend to be classified as color-neutral, i.e. without a clear undertone (dM).

4.3 Test conditions and testing procedure

Each sample is measured 50 times in immediate succession at the same measuring spot. The spectro2guide Pro is directly connected to the smart-lab Color software, this enables a triggered online measurement via software to minimize the user influence. The measurement data is also analyzed in the smart-lab Color software.

4.4 Results

The goal of any spectrophotometer is to measure what you see. This goal was successfully achieved during the test. The special Pro models, spectro2guide Pro and color2view Pro, can sort the samples "Test 1" to "Test 6" in terms of blackness level and Undertone according to the visual assessment. In Figure 4, the measured black value M_Y and the results for the undertone dM of all test tiles are shown graphically.

The measurement reliability can be best judged by analyzing the measurement accuracy meaning the repeatability performance to the spectrophotometer. In the following, the results for sample “Test 6” are presented as an example, as this is the ultimate black being at the upper end of the black scale with M_Y max = 400. Sample “Test 6” achieves an average black value of 378, which corresponds to a measured Y of 0.0116 on average. Despite a remission of only 116 parts per million of the incident light, the obtained standard deviation of Y is only 0.0002 (Variance ≙ 0.0172) for 50 measurements. Figure 5 shows the achieved results for M_Y. Figure 6 shows the results of Y measured with the color2view Pro.

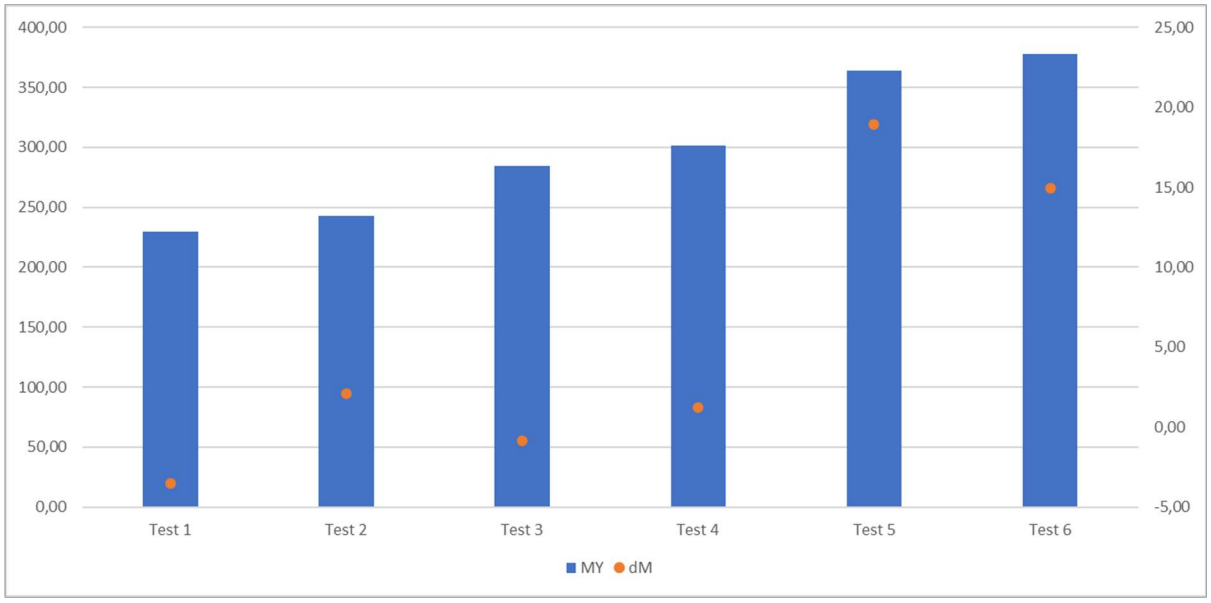

Fig. 4: Blackness value M_Y and Undertone dM of Test Tiles 1-6

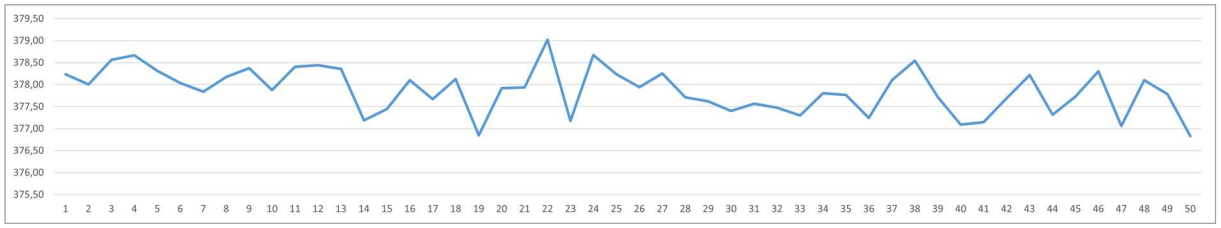

Fig. 5: M_Y of Test Tiles 6 measured 50 times

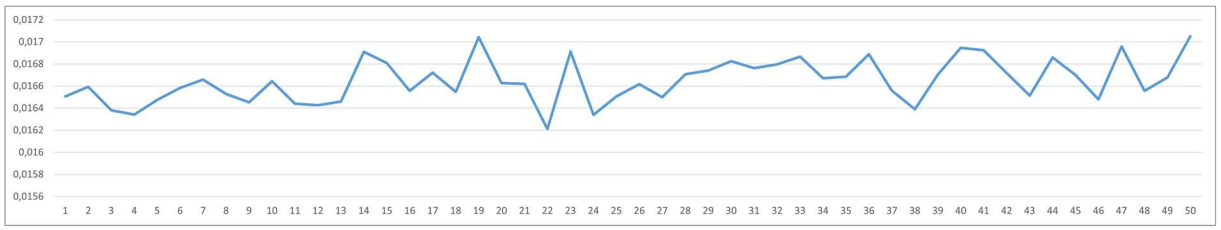

Fig. 6: Y of Test Tiles 6 measured 50 times

5 Summary

The challenge to objectively measure deep black colors repeatable and reliable was mastered using the Pro-models of BYK Instruments handheld and benchtop spectrophotometers. The technical performance is outstanding even on deep black samples with a blackness value M_Y value close to 400. The Pro-models open completely new perspectives to control color harmony of any color even deepest blacks with an unsurpassed accuracy needed for reliable quality control as well as a good correlation to our visual perception.

6 Literature and Standards

[1] Analytical colorimetry - Part 3: Special indices (ISO 18314-3:2015), German version EN ISO 18314-3:2018

[2] Pigmente - Bestimmung der Schwarzzahl von Pigmentrußen, DIN 55979:2020-12