THE STUDY OF COLOR CONTROL FOR THE AUTOMOTIVE OPERATORS

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ABSTRACT: *Numerous automotive operators are concerned with ensuring the homogeneity in the colors of different parts that compose their products. This quality objective of primary importance is especially challenging when the parts are sourced by different suppliers. The technical difficulties are accentuated when metallic or pearly paints are used since the presence of metallic chips in the paint causes a variation in the color according to the angle of observation. The present study responds if it is appropriate to use the spectrophotometer as the only decisive device for evaluating colors. To achieve this, critical colors and significant parameters affecting colors are identified, design of experiments is used to optimize the process settings, and a correlation study allows further process improvement Also, this case study therefore illustrates how quality tools can be used in a rigorous search for process improvement toward total color mastering with zero defect objective.*

KEY WORDS: *Color control, Process monitoring, Spectrophototometer.*

JEL CLASSIFICATIONS: *C1, C6.*

1. INTRODUCTION

The Romanian Automotive market has been growing by 18% year-on-year average since 2009 and is forecasted to exceed EUR 20 bn by 2020. It is the 4th biggest automotive manufacturer in the CEE and the 2 big automotive manufacturers at Craiova and Mioveni, FORD and DACIA have more than 600 OEMs for automotive supplies opened plants in Romania, directed at the local producers as well as to export.

In various industrial sectors, such as the cosmetic or luxury sectors, visual appearance plays a decisive role. Having become an evaluation criterion in the purchase of a vehicle, the buyer selects the brand, the model and then the color, before choosing the technical and ergonomic characteristics. Thus, color being an important quality factor, manufacturers must also have imagination and originality in conceiving new

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colors and trends in the automotive sector. As the automotive sector is governed by appearance and effects, buyers want a balance between the car's color and its shine, and both to represent it.

Our research is ongoing within the project “Ricerca nel processo di identificazione dei codici colore con spectrofottometri avanzati applicabili in condizioni operativi reali per migliorare l’efficienza dei processi di verniciatura nelle carrozzerie” which the University of Petrosani is carrying out in collaboration with operators from the automotive sector in Italy.

Whatever the cause, accident or for sale, a vehicle may require a repair of a specific element, of a certain area, repair that must be undetectable and invisible to the customer. Depending on the color formula used, there are different repair techniques. One of these techniques is that of spot repairs where the color formula is perfectly closed - this is the case with small bursts of color -. If the area to be repaired is larger, the element must be dismantled, modified, painted and reinstalled. Finally, when a color difference can be observed between the original color and the proposed formula, without being able to improve the quality, in order to reduce the color differences, the paint is also sprayed on the adjacent elements, this last technique known as "blending ”helps reduce color differences.

Reproducing the color of a car requires a lot of experimentation. It takes many years of training to learn how to choose color. Therefore, beyond the paint itself, paint manufacturers such as CROMAX, BASF, provide customers with color formulations that allow the reproduction of every color shade of the automotive fleet, namely several hundred thousand colors. Each color consists of a mixture of different ingredients that, when mixed together, provide a paint with a correct match or at least the best possible color. There are two categories of car paint solid and effect colors. Solid colors are based on the mixture of several primary colors. For effect colors, metallic or pearl, on top of the primary color mix, effect particles are added to provide certain optical properties. Depending on the angle of view, the interactions between light and matter produce different effects. Particles added to the paint film produce local optical effects depending on the viewing angle. These effects could alter the lightness and/or hue of the color itself. They are responsible for the heterogeneity of the optical film behavior and therefore the effect (texture).

Color formulas are developed in the laboratory by using matching software that integrates statistical models with optical physics. These models, used to estimate the resulting color from a formula or the reflectance curves that come from measurements made with spectrophotometers. These measurements are processed by various algorithms to minimize the theoretical color differences between the standard formula and the resulting formula.

Prediction models have their own limitations and the colorimetric description does not allow a complete representation of the visual perception of colors. The commonly used color descriptors, CIELab coordinates, are quite efficient for solid - pastel colors, but not efficient enough for metallic or pearl effect colors. Indeed, there are currently no visual texture descriptors that properly characterize these effect colors, and thus the overall appearance is not perfectly described. The result obtained during the formulation process is not accurate enough to obtain a good match after the first attempt.

This must be repeated several times by an experienced colorist who manually adjusts the formula to achieve a satisfactory formula. Based on his own experience, the colorist is able to reproduce a color. It is also important to note that aspects of efficiency and repeatability depend on the human factor.

2. LITERATURE REVIEW

Computerized colorimetric interpretations are based on a trichromatic system that can define any color as a combination of three basic colors in uniquely specified quantities (the fundamental colors are chosen so that none can be obtained by mixing the other two). The best-known trichromatic system is the RVI system (R-red, V-green, I-indigo) characterized by the three basic colors having the following wavelengths: red λ =700 nm; green λ =546,1 nm; indigo λ = 435 nm.

Any spectral monochromatic color in a trichromatic system is characterized by three values called spectral values or distribution coefficients. In the RVI system, there are colors that are also characterized by negative coefficients (negative coordinates of the basic colors). In order to eliminate negative values when specifying a color, three virtual colors (marked with X, Y, Z) have been defined that no longer present the specified inconvenience. These colors constitute the fundamental color values in the CIE (Commission Internationale De L'Eclairage) trichromatic system, being also called trichromatic coordinates or tristimulus values.

Characterization and measurement of colors in trichromatic systems In the CIE system, a color can be represented graphically in a three-dimensional system by the coordinate point (X,Y,Z). The totality of points corresponding to all possible colors constitutes the color space - Figure 1.

Color measurement in the CIE system consists in determining the X,Y,Z values. For this purpose, the three factors that characterize the color are considered, namely:

• the illuminant, represented by the energy distribution curve E(λ);
• the colored body, represented by the remission curves (reflection) R(λ);
• the human eye characterized by the spectral distribution curves for the normal observer $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$.

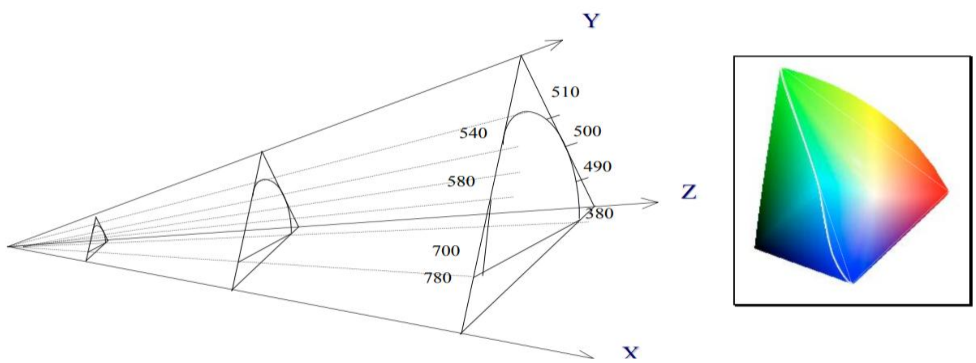

Figure 1. Color space in the coordinate system CIE XYZ

For a wavelength λ the energy transmitted by the colored body is equal to the product E(λ)·R(λ). The transmitted energy for all wavelengths of the visible spectrum (φ) is equal to ∑ E(λ)·R(λ) and represents the illuminantbody interaction λ. To determine the illuminant - colored body - eye interaction, the function φ must be multiplied by each of the three functions $x(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$.

The three calculation formulas are thus obtained for x,y and z:

$$X = \sum_{\lambda=380}^{770} E(\lambda) \cdot R(\lambda) \cdot \bar{x}(\lambda) \tag{1}$$

$$Y = \sum_{\lambda=380}^{770} E(\lambda) \cdot R(\lambda) \cdot \bar{y}(\lambda) \tag{2}$$

$$Z = \sum_{\lambda=380}^{770} E(\lambda) \cdot R(\lambda) \cdot \bar{z}(\lambda) \tag{3}$$

For calculations, the sizes $E(\lambda) \cdot \bar{x}(\lambda), E(\lambda) \cdot \bar{y}(\lambda), E(\lambda) \cdot \bar{z}(\lambda)$ are standardized and entered in the tables so that with a measurement only the remission curve R(λ) remains to be determined.

For the system CIELAB 76 the trichromatic coordinates X, Y, Z are transformed into three other coordinates:

L^* brightness coordinate;
a^* red- green coordinate;
b^* yellow-blue coordinate.

$$\begin{cases} L^* = 116 \cdot f\left(\frac{Y}{Y_0}\right) \\ a^* = 500 \cdot \left[f\left(\frac{X}{X_0}\right) - f\left(\frac{Y}{Y_0}\right)\right] \\ b^* = 200 \cdot \left[f\left(\frac{Y}{Y_0}\right) - f\left(\frac{Z}{Z_0}\right)\right] \end{cases} \tag{4}$$

where X_0, Y_0 and Z_0 are trichromatic coordinates which are obtained in the case of a material with a perfectly white reflective surface:

$$\begin{cases} X_0 = \sum_{\lambda=380}^{770} E(\lambda) \cdot \bar{x}(\lambda) \\ Y_0 = \sum_{\lambda=380}^{770} E(\lambda) \cdot \bar{y}(\lambda) \\ Z_0 = \sum_{\lambda=380}^{770} E(\lambda) \cdot \bar{z}(\lambda) \end{cases} \tag{5}$$

$$\text{and} \quad f(\phi) = \phi^{1/3} - \frac{16}{116} \tag{6}$$

The visualization of colors in the CIE Lab system can be seen in Figure 2. Luminosity is measured in depth, red-green horizontally, and yellow-blue vertically.

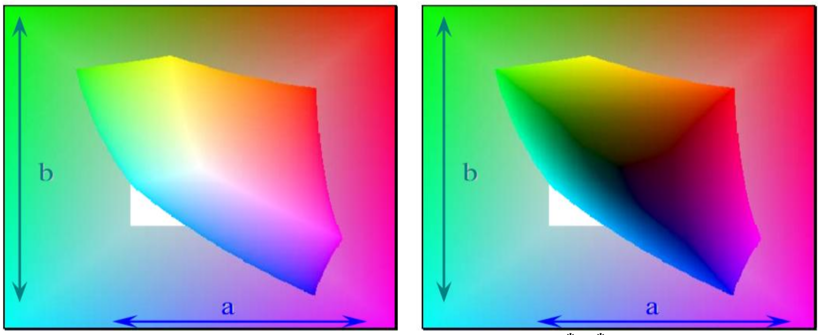

Figure 2. Color space CIE La* b*

The color difference ΔE^* between two color samples represents the geometric Euclidean distance between the corresponding points (of the two samples) in the color space. In the CIELAB system, it is calculated using the formula:

$$\Delta E^* = (\Delta L^*2 + \Delta a^*2 + \Delta b^*2)1/2 \tag{7}$$

where: ΔL^* represents the brightness difference between the two samples,

Δa^* represents the difference between the red-green coordinates,

Δb^* represents the difference between the yellow-blue coordinates.

3. DATA SERIES AND SPECIFICATION OF THE MODEL

Spectrophotometer, the equipment for measuring color is indispensable to process improvement. We used a Byc-Gardner Spectrophotometer model 6230. The color space is the system for coding colors. Several color spaces exist, but the one used for the present research has an almost spherical shape identified as L, a*, b* ; where L, a*, and b* correspond to the three axes of the space - Figure 3.

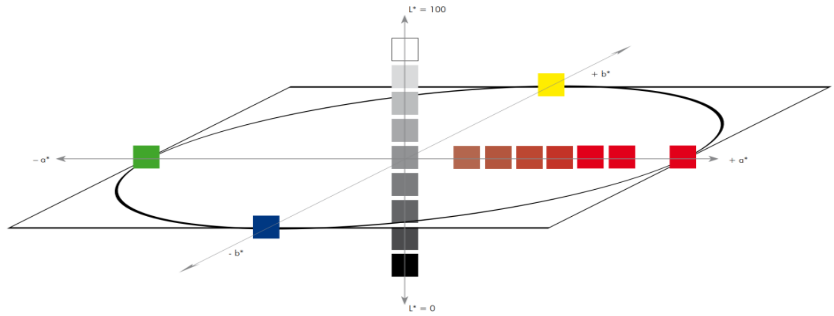

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Figure 3. Color space CIE Lab –methods of determination

Axis L represents the brightness of the color. Axes a* and b* are the chromatic axes, a* being the green – red axis and b*, the blue – yellow axis. The spectrofotometer is made of three sets of flash lamps. The light reflected by the surface of the specimen to be measured is collected by the sensors and analyzed, according to three angles: 15°, 45°, and 110°. The 15 angle corresponds to a viewing angle perpendicular to the specimen. The results of the analysis can be presented to the user as a spectral curve and a set of color space coordinates.

We built a model based on 48 color measurements taken on 48 different cars. For each of these we performed 2 or 3 measurements to highlight the color differences between different samples. In this study we exemplify the color differences found for different measured car colors.

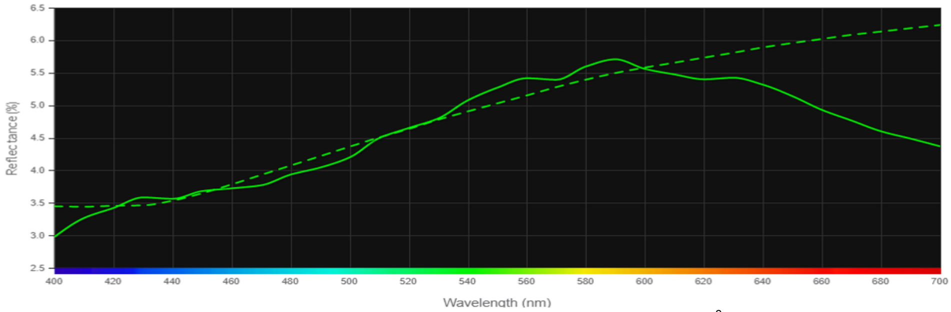

Figure 4. Reflectance curve measured at 15°

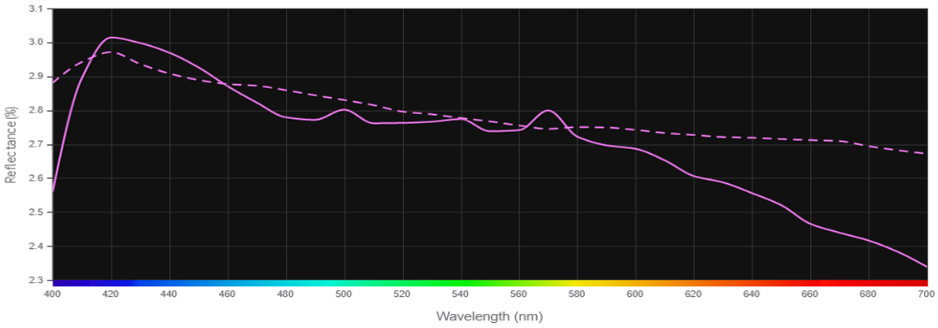

Figure 5. Reflectance curve measured at 45°

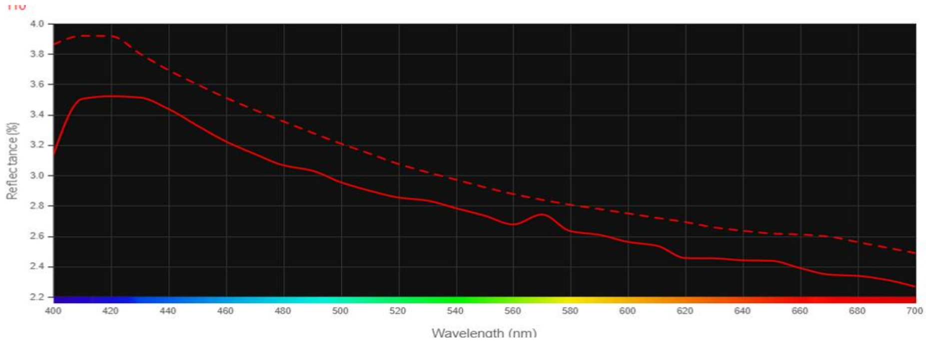

Figure 6. Reflectance curve measured at 110°

We have used the spectrophotometer as a monitoring instrument to determine color differences between the measurements made on the same autovehicle using identical condition for illuminance. The technical difficulties are accentuated when metallic or pearly paints are used since the presence of metallic chips in the paint causes a variation in the color according to the angle of observation We have measured these differences and represented them in Figure 4. Reflectance curve measured at 15, in Figure 5. Reflectance curve measured at 45 and Figure 6. Reflectance curve measured at 110° for one sample.

The largest uncertainty observed is related to the brightness L. The spectrophotometer is used as a tool for progressing efficiently towards the objective of zero color deviation. Nevertheless, the human eye remains the only judge in case of disagreement between the visual impression and the results given by the spectrophotometer.

By using spectrophotometer and color samples, the differences of colored car bumpers is improved to better respect the customer specifications for color matching between components. Critical colors and significant parameters affecting colors are identified, design of experiments is used to optimize the process settings, and a correlation study allows further process improvement.

4. **CONCLUSION**

Therefore, it is not appropriate to use the spectrophotometer as the only decisive device for evaluating colors. It is rather useful for the measurement of the progression of the color (quantification of color differences, statistical treatment of the measurement to determine yield) or as a monitoring instrument for the color in process because of its ease of use, the rapidity for control, and since no particular lighting is required.

The critical colors and significant parameters affecting colors are identified, in mettalic and pearly components. Also, this case study therefore illustrates how quality tools can be used in a rigorous search for process improvement toward total color mastering with zero defect objective.

The results achieved are: identifying the differences for some critical colors, better understanding of the factors influencing the colors. In the next steps of the project we will check the colour differences resulting from the calculation formulas. We will also will try to calculate the influence of weighting factors for the automotive sector.

REFERENCES:

[1]. CIE (2001) *Technical Report: Improvement to Industrial ColourDifference Evaluation*, CIE Publ. No. 142 (Vienna: Central Bureau of the CIE)

[2]. CIE (2004) *Colorimetry*, CIE Publication, 3rd Edn (Vienna: CIE)

[3]. Hiller, G. (2019) *Color-management ebook-3-en* Datacolor, Inc Princess Road, Lawrenceville, USA https://www.datacolor.com/business-solutions/color-management-e-books-pt/color-management-flipbook-book-3-pt/

[4]. Luo, R; Cui, R.; Rigg, B. (2001) *Col. Res. Appl.*, 26(5), 340

[5]. Perz, M. (2010) *Flicker perception in the periphery*. Master, University of Eindhoven.

[6]. Melgosa, M., et al. (2014) *Measuring color differences in automotive samples with lightness flop: a test of the AUDI2000 color-difference formula.* Optics Express, 22, 3458-67

[7]. Munsel.Color (2019) *The Munsell Color Tree* [Online]. Available: https://munsell.com/colorblog/color-tree/, [Accessed 08//09/2023]

[8]. Vienot, F.; Le Rohellec, J. (2013) *Colorimetry and Physiology* **-** The LMS Specification. Digital Color

[9]. Wyszecki, G.; Stiles, W.S. (1982) *Colorimetry. Color science : Concepts and methods, Quantitative Data and Formulae*

[10]. Wright, W.D. (1969) *The Measurement of Color*, 4th edn, Hilger, Bristol

[11]. X-RITE (2018) *MA-T_The new way to characterize effect finishes Tolerancing Part 2 : The Role of Light* [Online], Available: https://www.xrite.com/blog/tolerancing-part-2-the-role-of-light, [Accessed August 13th 2023]

[12]. https://www.audi.com/ci/en/intro/basics/imagery.html, [Accessed 08//09/2023]