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**COLORIMETRIC CHARACTERISTICS OF THE LIGHT
EQUIPMENT IN THE AUTOMOBILE-INDUSTRY**

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Abstract

Modern Illustrated magazines with colorful illustrations, color photos, various sorts of materials, plastic colored materies, goods in colored packages, colored optical glasses, all that indicate increased importance of colors in the everyday life. Color has become subject of interest, not only for artist but also for engineer, chemician, phisician. The science, engaged in measuring colour, is named colorimetry.

The very important characteristics of the plastic masses aimed for the light equipment in the automobile-industry, are the colorimetric characteristics.

In this project, there are given some results of measuring the colorimetric characteristics of different plastic masses, aimed for the light equipment, with the help of the machine Topcon in the factory "21. October".

Keywords: *colorimetry, colorimetric characteristics, plastic masses*

1. INTRODUCTION

Colors are those light characteristics which differ from the time and space non-homogeneity; here the light is understood as the radiation energy that man absorb through the visual sensations that appear because of inducing his eye's retina. The light characteristics are first the light flux that is the measure of light efficiency, while inducing the sensation of glowing. The other two characteristics which are together marked as the light chromaticity are the dominant wavelength and the cleanliness. The aim of colorimetry, the branch of psychophysics, is to give a simple and precise way of measuring and specification of the light that is emitted from the source or reflected from some other object.

**2. THREE-CHROMATIC EYE SIGHT
CHARACTERISTIC**

If the light source is monochromatic, its visual effect can be shown in two dimensions. One is the light flux:

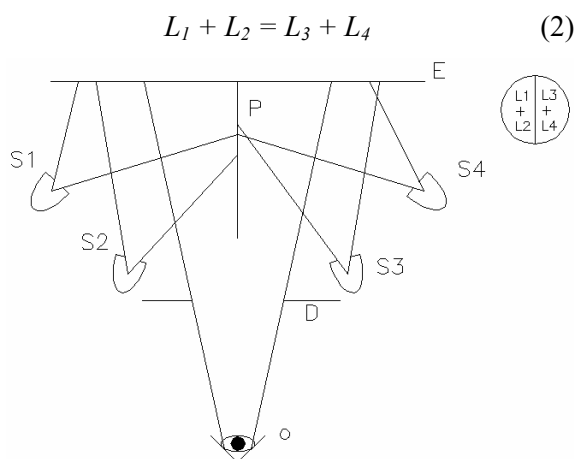
$$\Phi = K_m y_A P \quad (1)$$

that shows if the source is more or less bright, while the light color is determined by the radiations wavelength. In that sense, the eye is an unique receptor, because the influence of monochromatic source on the other receptors, can be shown in only one dimension, which is the light flux, that is determined by the above mentioned equation. Factor y_A , is then corresponding relative receptor sensitivity.

The lights of different spectral characteristics and of the same color are called met meters. For each light color, there are an endless number of the parameters, and the met metricity degree determines the size of difference between their spectral characteristics. It is experimentally established that eye-sight has three variants, which means that beside the flux there are only two more dimensions needed to show the visual effect of radians of continuing spectrum. Because of that, it is said that the eye-sight is of the three-chromatic nature.

Adding of the light flux

In the picture 1, it is shown the method of working of the colorimeter. The shelter (E), that is divided into two parts by the partition (P), reflects equally and diffusely all radiation of the visible part of spectrum. When one part of the shelter is illuminated by the light sources (S1) and (S2), and the other part is illuminated by the (S3) and (S4), the glowing of both parts can be equalized by changing the source equation.



Picture1: Schemical survey of the method of working of colorimeter

The ring at the right side marks the appearance of the field seen from the point O.

If the colors of both halves of the visible spectrum are equal, then the given condition is expressed by the colorimetric equation:

$$L_1 (S_1) + L_2 (S_2) = L_3 (S_3) + L_4 (S_4) \quad (3)$$

Where $L(S)$ is marked by (L) , that is the light unit, (S) u fotometrijskim jedinicama sjajnosti, $[cv/m^2]$.

It is possible to show that a mixture of endlessly many monochromatic sources is an equivalent to a mixture of white light with some determined monochromatic light, or that is:

$$\sum_{(n=1)}^{\infty} Ln(\lambda n) = Lw(W) + L_{\lambda}(\lambda) \quad (4)$$

Equation (4) is an experimental confirmation of three variants of the sight characteristics. At the right side, there are only three variable dimensions: dominant wavelength, (λ) and two glowing units (L_w) and (L_{λ}) . It is interesting to mention that the color of the monochromatic source in the equation (4) is equal as the color of the complex light, it is only more intensive. Besides, the dominant wavelength (λ) is usually found in the vicinity of the spectral characteristic of the complex light.

From three dimensions that according to the equation (4), can define the characteristics of light of all colors (apart from purple), it is only used the dominant wavelength (λ) . Other dimension, that is used is $L = L_w + L_{\lambda}$, or the mixture glowing, and the third is $p_c = L_{\lambda} / L$.

If (λ) , in the equation (4) is not changed, then the basic light color will not be changed, but with the change of the relations between (L_w) and (L_{λ}) , the light color will appear to be more or less intensive. If the case is that $L_{\lambda} = 0$, then the light is white, and if there is $L_w = 0$, then the light is monochromatic or the pure color. That means that adding of white color reduces the colorimetric purity color p_c , or its saturation. Bright colors are the colors of great saturation, while the saturation of pale, pastel color is small. The colorimetric purity is dimension that determines on of the light characteristics. The colorimetric purity determines the relation between the glowing of monochromatic component in mixture and the glowing of mixture, and it marks psychophysical dimension, that can be measured. The colorimetric purity is constant and it is equal as the unit for all monochromatic lights. The saturation is purely the psychological dimension which determines the degree of difference between a certain color and the white. Opposite to the colorimetric purity, the sense of saturation is not constant for the monochromatic colors. n. Yellow color for example, looks as the less saturated than violet color, of the same colorimetric purity.

3. COLORIMETRIC UNITS

Measuring or specification of colors can be done with the help of three appropriately chosen monochromatic lights. Measuring consists of determining the relative relations between the light fluxes quantities, which are needed for the colors agreement. The chosen monochromatic lights are then called primar sources or the primars, and primars' quantities needed for the color specification, are not expressed in the units of glowing, as it was the case with the proceeding member. According to the agreed standard white color, for this purpose, it is used a special unit. Suppose that the light with even energy distribution is adopted for the standard light (W light), and that the wavelengths of monochromatic primars are $\lambda_1 = 700$ nm, $\lambda_2 = 546, 1$ nm and $\lambda_3 = 435, 8$ nm. These lights are of red, green, and blue color, and they are

usually marked as (R), (G) and (B). In order to express color in colorimetric units, one should determine the quantities of primars in colorimeter, needed for the agreement of the referent white color. The light with even energy distribution cannot be produced in laboratory. Because of that, measuring is performed with other standard source of white color, and necessary informations are collected through calculations. Suppose that those are Φ_{RW} , Φ_{GW} , Φ_{BW} fluxes. If we illuminate one side of the colorimeter with a source (S) of one unknown color, and if we establish that the colorimeter is balanced when the light fluxes of some primars are Φ_{RS} , Φ_{GS} , Φ_{BS} , apart from these psychophysical units, we can express the light (S) in the quantities of the colorimetric units.

These quantities are defined with the following relations:

$$R = \frac{\Phi_{RS}}{\Phi_{RW}}, \quad G = \frac{\Phi_{GS}}{\Phi_{GW}}, \quad B = \frac{\Phi_{BS}}{\Phi_{BW}}. \quad (5)$$

So the light t(S) is defined with the quantities (R), (G), (B) of the appropriate primars (R), (G), (B) or we can say it with the mixture of green primar units G, red primar units R, and blue primar units B. Considering that, the absolute quantities of the colorimetric units are connected with the white referent light, so that the mixture consisted of one unit of each primar, produces the white light.

The colorimetric equation expressed in new units is:

$$K(S) = R(R) + G(G) + B(B), \quad (6)$$

And the quantity of the produced light (S) is equal as the sum of the quantities of the primar lights.

$$K = R + G + B \quad (7)$$

According to the Grossmann's Law, we can conclude that the arithmetic of members in the colorimetric equation is equal as the arithmetic of the ordinary numbers. For example, if the two colors are determined with the following equations:

$$K_1(S_1) = R_1(R) + G_1(G) + B_1(B) \quad (8)$$

$$K_2(S_2) = R_2(R) + G_2(G) + B_2(B) \quad (9)$$

the produced color is:

$$\begin{aligned} K_3(S_3) &= K_1(S_1) + K_2(S_2) = \\ &= (R_1 + R_2)(R) + (G_1 + G_2)(G) + (B_1 + B_2)(B). \end{aligned} \quad (10)$$

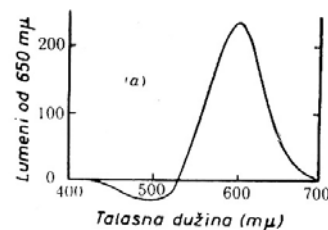
Components of the two colors mixture are equal to the sum of the certain colors components.

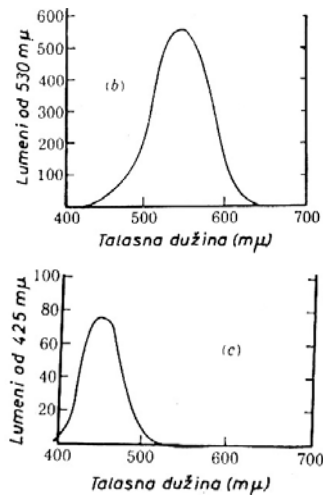
This equation will not be changed even if we multiply the both equations with some constant member. That means that the given equation will not be changed if we reduce or increase equally the glowing points of certain sources. Yet, it was established that this conclusion was not valid for the very small or the very big glowing points.

4. DEFINING OF THE SPECTRAL COLORS WITH A USE OF THE COLOR MIXTURE

When defining the colors, we do not absolutely need to use the colorimeter, in order to define the quantities of the three arbitrary components. A preliminary experiment consists of measuring of those components quantities that are needed for the definition of the spectral colors. (The spectral color is understood as the light beam, made of the narrow interval of the wavelengths). The components quantities needed for the colors definition can be calculated if we know the total flux of the heating radiation for the given color.

The picture number 2. shows for the certain components, the component quantities that are needed for the spectral color definition of the given wavelength.



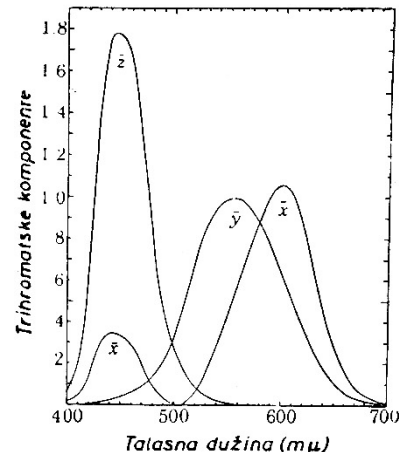


Picture 2: Luminary numbers for each of three monochromatic components, needed for the definition of monochromatic flux of the heating radiation of 1 W

According to their characteristics, these components are the spectral colors; the red is in the wavelength of 650 mμ, the green is in the wavelength of 530 mμ and the blue is in the wavelength of 425 mμ. The curve ordinates give that number of the each component luminary, that is needed for the definition of that additive mixture which total radiation energy for the given wavelength is 1 W.

The international board for the illumination (I.C.I.) (1931.) agreed on expressing all informations about the color mixture in three components, chosen so that the curves from the picture 2 would always above the X coordinate. With this it was avoided the usage of the negative numbers.

The standard I.C.I. curves for the color mixture are given at the picture 3. In order to make the calculation easier, the ordinates are expressed in the arbitrary units, so that the surfaces below each curve are equalized. The symbols \bar{x} , \bar{y} and \bar{z} are used for the ordinates of the appropriate curves. The values \bar{x} , \bar{y} i \bar{z} for any wavelength are called three-stimulus spectral color values for the given wavelength. It can be seen that the three-stimulus green light values for the wavelength of 500 mμ, $\bar{x} = 0,0049$ $\bar{y} = 0,3230$ $\bar{z} = 0,2720$.



Picture 3: Standard I.C.I. curves for the colors mixture

Since these three numbers (three-stimulus value) are needed for the color specification, we also need a three-dimensional diagram in order to describe the colors graphically. These difficulties can be avoided by introducing three new values x , y and z which are defined in the following equations:

$$x = \frac{\bar{x}}{x + y + z}, \quad y = \frac{\bar{y}}{x + y + z}, \quad z = \frac{\bar{z}}{x + y + z}. \quad (11)$$

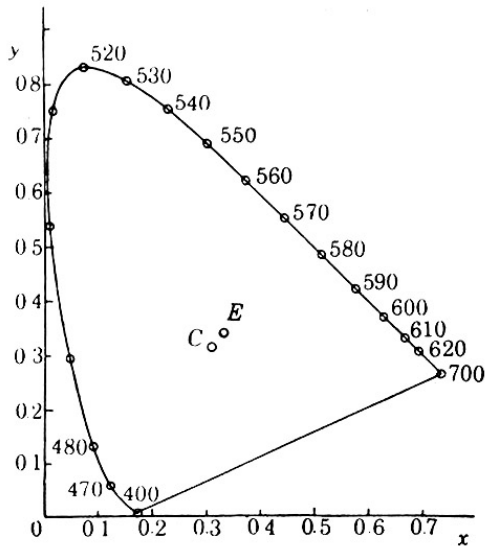
The values x , y and z are called three-chromatic coefficients. Since they are defined with: $x + y + z = 1$, we can conclude that two values are needed for the definition of some color. We usually choose the x and y values. If we take the spectral light of the wavelength 500 mμ, we will find out that:

$$x = \frac{0,0049}{0,5999} = 0,0082,$$

$$y = \frac{0,3230}{0,5999} = 0,5384,$$

$$z = \frac{0,2720}{0,5999} = 0,4534.$$

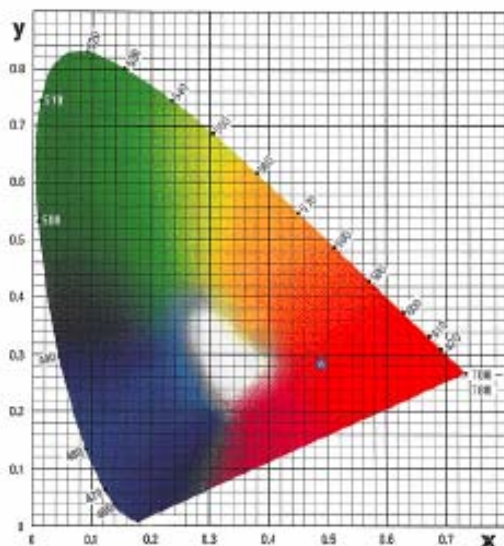
The spectral color can be also shown in the two-dimensional rectangular coordinate system with a point which coordinates are: $x = 0,0082$ and $y = 0,5384$. and If we do the same calculations for each color and mark the given results, we will see the curve which is shown at the picture number 4. The curve is called a spectral curve and the diagram is called a chromatic diagram.



Picture 4: The chromatic diagram at which the spectral curve is shown as well as the illuminators C and E

Three-chromatic coefficient of some color

Three-stimulus values for some light mark the quantities of the three I.C.I. standard components which when they are mixed define that light. These values are marked with X, Y, Z and they are calculated with integration. If we take that the total flux of the heating radiation at the wavelength λ of the given light is $f(\lambda)d\lambda$.



Picture 5: The chromatic diagram

The quantity of this first primar component, needed for this wavelength interval is then:

$$\bar{x}f(\lambda)d\lambda \quad (12)$$

And according to this the total quantity needed for the definition is:

$$X = \int_0^{\infty} \bar{x}f(\lambda)d\lambda \quad (13)$$

In the same way there is:

$$Y = \int_0^{\infty} \bar{y}f(\lambda)d\lambda \quad Z = \int_0^{\infty} \bar{z}f(\lambda)d\lambda \quad (14)$$

Since the curves at the picture 4 cannot be expressed in an analytical way, the integration must be carried out in the graphical, numerical, or mechanical method. There are some machines that can carry out the integration automatically and precisely. We can calculate the three-chromatic coefficients x, y, and z out of the three-stimulus values x, y, and z with the use of the following equations:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

When the upper procedure is carried out for the light which total flux of the heating radiation is equal for each wavelength, we get that $x = 0,333$, $y = 0,333$. Chromaticism of that sort of light is shown with a point E at the picture 4. The standard source of light, known as the illuminator C that replaces in a very satisfying way the day light, is shown with a point C.

5. THE RESEARCHING RESULTS

An accredited laboratory of the factory "The 21. October" in Kragujevac possesses modern measuring equipment with which they are able to define the coordinates of the measured color of one transparent subject with the use of the colorimeter, type Topcon. This machine serves for measuring the three-chromatic coordinates (x, y, z) of measuring field (0, 20, 0, 10, 1° i 2°) and with objective (f=80 mm). The subject which is measured is placed at such a distance from the machine so that the measuring field is within the subject. The colorimeter can measure color at the machines that posses the source of illumination, as well as at those that do not posses it. After adapting the machine, with h a slight pressure of the finger the colorimeter

starts with collecting the informations which can be seen automatically at the display. The machine is illuminated with the standard CIE source of light "A" – a bulb with a heated thread (the color temperature $T_b=2854$ K) and the reflected light beam coming from the machine, falls on the entrance of the colorimeter and goes over the system of lens filters to the to the sicilium photo-diode, out from where with a help of converter, we get the digital note in the shape of x , y , and L ,

where are: x and y – the chromatic coordinates,
 L – the measured lumination.

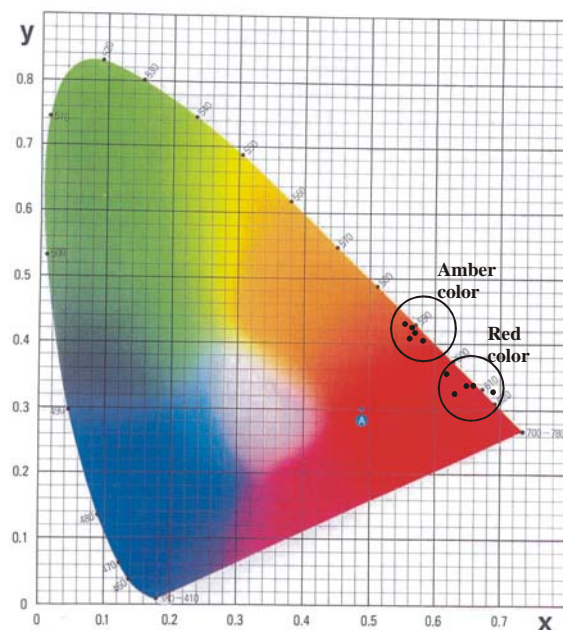
In the specification, predicted by the ECE book of regulations, the limits were defined that machines for the chromatic coordinates have to satisfy:

The results of researching are compared the standard values that are given for each color and that are defined with the ECE book of rules.

This way of measuring enables us to reveal all the mistakes regarding the choice of colors and its quality, for the machines with the light signalization, in order to fulfill the standards and to provide the best functioning of all machines and the exploited. The measuring of the lumination and the chromatic characteristic, were done within the preliminary researching of the light equipment characteristics. The measurings were done at the light transparent, at the direction signal, at the stopping light, and the light for driving backwards. These lights were made by the same tools but from the plastic masses of the different colors. Transparent are made from the polimetaitmetaakrilat - PMMA, wit the squirting technology.

red color	the limit is next to the yellow	$y < 0,429$
	the limit is next to the purple	$z < 0,008$
amber color	the limit is next to the yellow	$y < 0,429$
	the limit is next to the red	$y > 0,398$
	the limit is next to the purple	$z < 0,007$
white color	the limit is next to the blue	$x > 0,310$
	the limit is next to the yellow	$x < 0,500$
	the limit is next to the green	$y < 0,440$
	the limit is next to the red	$y > 0,382$

Measuring was done at the number of the transparents, made of the plastic mass PMMA in different colors: red, yellow and blue. Transparent manufacturing underlined the change of some technological parameters on the machine for squirting. Some of the obtained results are shown at the picture 6.



Picture 6: The chromaticism diagram

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6. CONCLUSION

The theoretical and experimental researching which was started in this project has an aim of studying the influences of the technological parameters of the squiring elements to the anticipated quality. The products quality can be confirmed with the measuring of the colorimetric characteristics. The developed model that possesses all the information about the technological parameters and about the achieved quality would enable its mutual relations, and make a base for the development of an expert team in the field of the tools projecting and the technology for manufacturing the elements out of the plastic masses. In that way one could predict the final quality of a product at all manufacturing phases. Realized researching showed that the measured values of the chromatic characteristics for the red and the yellow color were within the expected limits, but that could not be said for the white color. The influence of the technological parameters, that had variations in one narrow field, showed that there were no important influences on the products colorimetric characteristics. From some other point, preparing the tools, especially cleaning it from the previously squirted plastic mass, showed that it had an important influence.

7. REFERENCES

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