COLOUR PREDICTION OF CERAMIC GLAZES WITH THE KUBELKA-MUNK MODEL

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ABSTRACT

In this study the efficiency of the Kubelka-Munk model (already known and consolidated in other industrial sectors) was evaluated by using it to predict the colour of an opaque ceramic glaze obtained by a mixture of yellow zircon-praseodymium pigment ((Zr,Pr) SiO_4) and zircon opacifier ($ZrSiO_4$). Glazes with different percentages of yellow pigment and opacifier were prepared to determine the absorption and scattering optical constants of the Kubelka-Munk model with the reflectance curves provided by a spectrophotometer. The L, a*, b* parameters obtained of the glazes were confronted with the date of absorption and scattering of light obtained with Kubelka-Munk model. It was verified that there is no linear relationship of the a* and b* parameters with the concentration of yellow Pr-doped zircon pigment. On the other side a linear function between the optical constants of the Kubelka-Munk model with the concentration of the yellow zircon-praseodymium pigment was verified. This model is currently used in computational software and allows quick obtainment of a specified colour formulation.*

1. INTRODUCTION

In the tile industry the control of the colour is generally made using the CIELab system, through the measure of L*, a*, b* parameters. But unfortunately this system has some limitations[1]. In fact there isn't a systematic relation between the L*, a*, b* values and the concentration of added pigments. Recently, with the introduction also in the ceramic tile industry of colorimetric systems, this control can be made by the Kubelka-Munk model because the computational softwares for colour formulation use the Kubelka-Munk theory.

The Kubelka-Munk[2] model relates the colour (reflectance) with the concentration of added pigments:

$$\left(\frac{K}{S}\right)_M = \sum \frac{K_i c_i}{S_i c_i} = \frac{(1-R)^2}{2R} \qquad \textit{Equation 1}$$

where K/S is the adsorbed light by a mixture of pigments; ci are the concentrations of the added pigments, K_i and S_i are respectively the absorption and scattering coefficients and R is the reflectance measured with a spectrophotometer.

2. PROCEDURE

The coloured glazes were prepared by mixing 92 wt% frit, 8 wt% kaolin and different percentages of yellow pigment and opacifier zircon, as showed in Table 1. The wet milling was made with 50% water in a ball mill for 20 minutes. Cylindrical samples of glazes were prepared pressing the powder (6 wt% of water) with a laboratory press. The samples were fired in a semi industrial kiln at 1175°C ± 10°C with a cycle of 35 minutes. After the glaze firing, the reflectance curves and the L*, a*, b* parameters were measured by a Datacolor Spectraflash 600 spectrophotometer with geometry d/8, illuminant D65 and observer 10°.

	% YELLOW PIGMENT	% $ZrSiO_4$	L*	a*	b*	K/S
Yellow glazes	5.0	-	91.0	- 3.4	45.0	1.05
	3.0*	2.0	92.1	- 3.9	38.7	0.70
	2.5*	2.5	92.7	- 4.0	35.0	0.56
	1.0*	4.0	94.1	-4.3	24.5	0.27
	0.5*	4.5	94.8	-3.6	18.0	0.15
Glaze + opacifier	-	5.0	96.2	- 0.7	2.1	0.01

Table 1. Concentration of yellow pigment $(Zr,Pr)SiO_4$ and opacifier $(ZrSiO_4)$ in the prepared glazes and L, a*, b* and K/S (420 nm) parameters values.*

3. RESULTS

In Table 1 the L*, a*, b* parameters of the glazes as function of the concentration of the added pigment are showed. The L* parameter (lightness) reduces as the pigment concentration is increased, as expected. The a* and b* parameters, instead, have

random changes with difficult interpretation underlining the difficulty to use these parameters for the colour formulations. From the reflectance curves of the prepared glazes the K/S ratio was calculated at 420 nm. The Kubelka-Munk absorption increases with a linear tendency (Figure 1). This behaviour indicates that with the Kubelka-Munk model is possible to systematically relate the obtained colour with the quantity of added pigment.

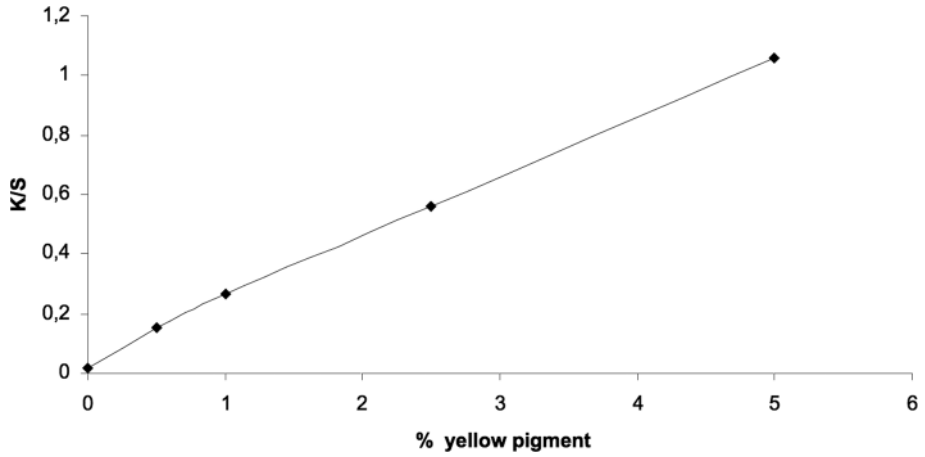

Figure 1. Kubelka-Munk absorption as a function of the yellow pigment concentration in the glaze.

4. CONCLUSIONS

Even if the L*, a*, b* parameters are very widely used in the control and formulation of ceramic glaze colour is difficult to evaluate their behaviour with the concentration of added pigments. With the proposed Kubelka-Munk model is possible to relate the colour with the pigment and opacifier concentration and to make predictions of the developed colour with a good accuracy.

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