

Hue Variation on Ceramic Tile During the Decoration Stage by Laser Engraved Silicon Cylinders Method

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Abstract. Hue variation is a common problem in the ceramic tile industry. Despite the growth of the digital decoration in recent years, a considerable part of the ceramic tiles is still decorated by the more traditional technique using laser engraved silicone cylinders. In this scenario, the objective of the present study was to contribute to minimize the hue variation of ceramic tiles. To achieve this, the correlation between the viscosity of the ink and the geometric characteristics of the printed dots was studied. Some of the variables related to the decoration process were fixed. The viscosity of the ink was varied and the geometric characteristics of the dots were evaluated. In general the values measured for the reflectance, decrease with the increase of the viscosity, but there are cases where this variation shows an opposite behavior. As a conclusion, for each range of gray-scale values there is a range in viscosity that optimizes the ink transfer to the ceramic tile.

INTRODUCTION

In the construction industry, ceramic tiles settlement is one of the most important parts in the finishing phase of a house, an apartment or even in an important commercial center or an office building. There are basically two cases when people notice a floor or wall covered by a ceramic tile: when the surface is too beautiful or when it is noticed that something, somehow displeases the eyes. This unpleasantness feeling frequently is related to a non-observed, but felt; sharp hue variation.

Worldwide, the volume of ceramic tiles (floor and wall) has increased year after year and new technologies and decoration systems keep boosting this increase. [1] In Brazil, this increase has great significance, for the last 6 years, the Brazilian production capacity has increased almost 52% and the effective production increased almost 51% in the same period. [2]

The study of hue variation has been investigated in some articles. Campos and co-workers [3] studied the variables that can affect the decoration cylinders, inks and its components, different types of decoration machines and different methods of fabrication of ceramic tiles. Sharma, K.D. [4] investigated the influence of hue variation caused by the pigment, glazes, engobes and tile color. In the industry, hue variation is one of the main problems faced by the producers, which can increase the inventories, late deliveries, loss of money, time, supplies, etc.

Motivated by these problems, this work aimed to investigate one of the characteristics inside the production line that has influence on the hue variation, either within a production batch or in a different batch; the influence of changes in ink density and viscosity.

Materials and Methods

The decoration way used in this work was the laser engraved silicon cylinders method (Rotocolor MPS™). The machine used was a Rotocolor S5 Universal™. Several variables were left fixed in attempt to control the study: flux and pigment (ENDEKA Ceramics Ltda); liquid medium (Zschimmer & Schwarz do Brasil Ltda); type of silicon and cylinder dimensions; kind of floor tile

(dry method tiles); decoration speed; blade angle and pressure; tile temperature before decoration; gray-scale percentage of the decoration area; cylinder high and engraving used.

The floor tiles were left in a muffle before the decoration. All the adjustments were realized and six different formulations were investigated. As it is done normally in the floor and wall tile industry, the inks were made based on the proportion calculus for a certain final density and viscosity. The flow time were measured with a n°4 Ford cup and the density measured by a isometric picnometer and a balance. Hereinafter, it will be used the term “viscosity” in reference of flow time of the ink, as these two magnitudes are directly proportional. The chosen flow times were within and without the range indicated by the decoration machine used. Flow times lower than 16” for the ink weren’t tested because the medium itself had a time of 14”. So, the nominal viscosities used were 16, 18, 20, 22, 24 and 26s.

No additives were used to lower the viscosity because this is not the procedure usually used by Brazilian ceramic floor and wall tile producers. The images of the decoration area were obtained by optical microscopy, and the geometric characteristics of the dots were evaluated using an image analyzer. The reflectance data were also obtained using a spectrophotometer device.

Results and Discussions

The micrographs of the decorated samples with the evolution of the viscosities and densities tested for the 0,4/45° engraving are indicated in the Fig. 1, the photos of the decorated area with 5% of the gray-scale; in the Fig. 2 are the samples for 25% and in the Fig. 3 for the 85% of gray-scale. The figures also show the image after a software treatment to obtain the decorated percentage of surface area covered.

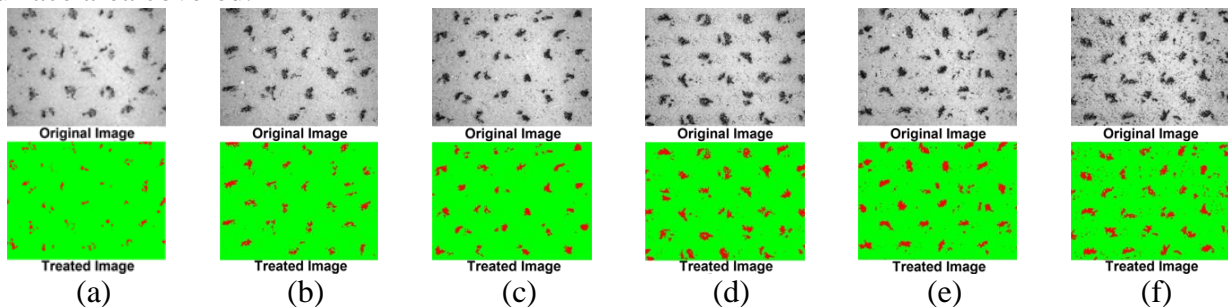


Fig. 1 – Decoration of 5% of Gray-scale with image analysis for the 04/45° engraving, with viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.

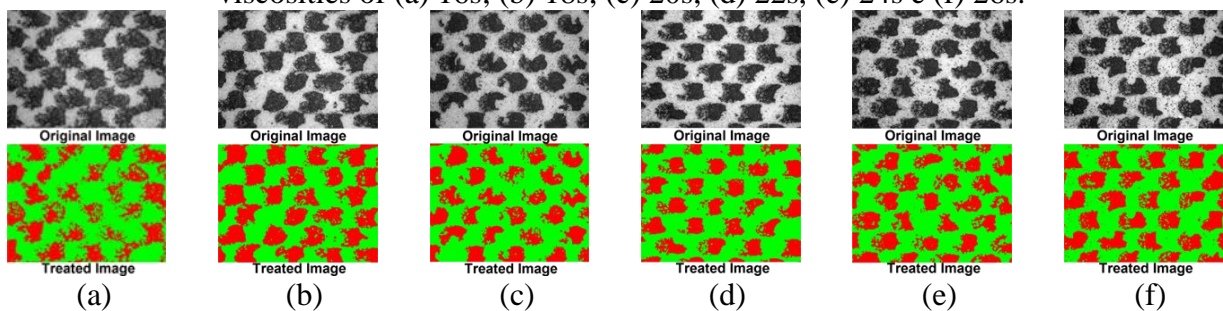


Fig. 2 – Decoration of 25% of Gray-scale with image analysis for the 04/45° engraving, with viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.

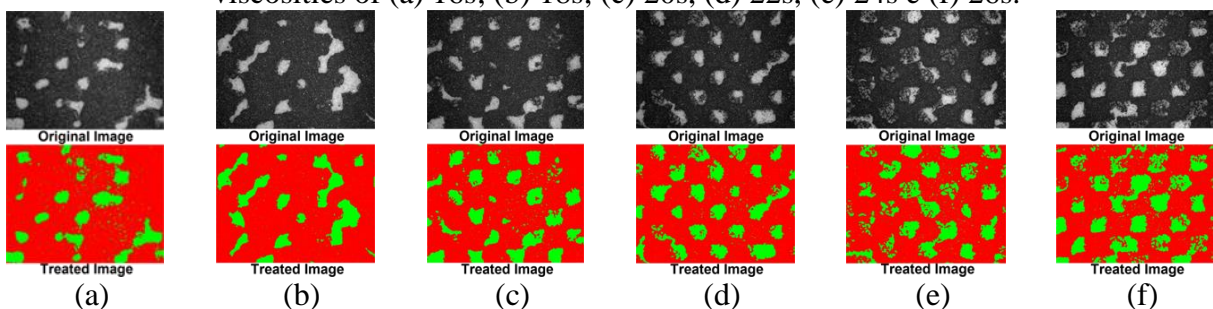
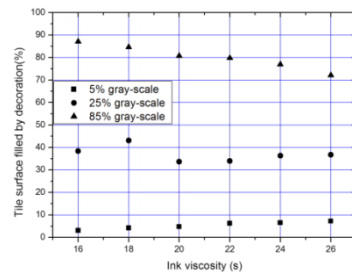


Fig. 3 – Decoration of 85% of Gray-scale with image analysis for the 04/45° engraving, with viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.

In Fig. 4 are shown the data comparing the evolution of the surface percentage recovering as the ink viscosity increases.

Fig. 4 – Decorated area recovering for the 5, 25 and 85% of Gary-scale areas for the 0,4/45° engraving with the viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.

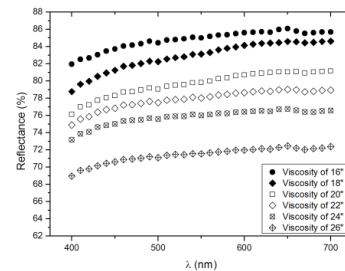


As can be seen in the micrographs of Fig. 1, mainly on the treated images; is that for the 5% Gray-scale decorated areas there is a growing tendency in the decorated dots filling and, consequently, the overall decorated area on the tile surface increases. It can be also observed that the decorated dots are non-regular in means of their shape (nor circle nor elliptic).

On the surface glaze it was possible to visualize the formation of little stains as the viscosity increases, consequence of a fail cleaning on the silicon cylinder surface by the steel blade, which leads to the formation of a thin film of ink that was passed to the tile.

The formation of this ink film over the cylinder (with high values of density) is due to the lack of lubrication of the solid part of the ink, which provides a faster ink drying on the cylinder surface, heated by the constant contact with the hot tile surface. In the Fig. 5, 6 and 7 are shown the graphics with the results of the spectrophotometer tests for the samples decorated with 5%; 25% and 85% of gray-scale.

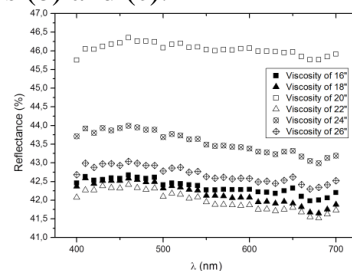
Fig. 5: Changing in reflectance values due to the increase of density and viscosity for the 5% of Gray-scale covering. 0,4/45° engraving.



In Fig. 5, the spectrophotometric analysis is that the light intensity reflected by decorated surface diminishes with the increase of ink viscosity and density. In the obtained data it can be seen that there is a better ink discharge by the cylinder alveolus over the tile surface, increasing dots filling and the percentage of decorated area. This analysis is congruent with the data presented in Fig. 4 and the analysis made over the micrographs presented in Fig. 1.

By the reflectance data for the samples decorated with the 25% of gray-scale area shown in the Fig. 6, it can be observed a slight increase in the dots filling (understood as a better ink discharge) when the viscosity increases from 16s to 18s, which can be seen between the images (a) and (b) of Fig. 2. With another increase in viscosity (to 20s), it can be seeing that there is a decrease in the quantity of discharged ink comparing the images (b) and (c).

Fig. 6: Changing in reflectance values due to the increase of density and viscosity for the 25% of Gray-scale covering. 0,4/45° engraving.



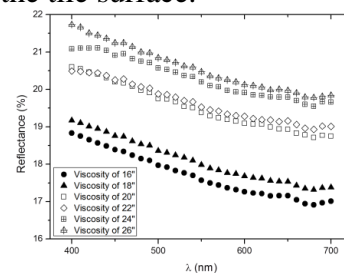
Although, according to the Fig. 4, there was no significant variation on the percentage of decorated area between viscosities of 20 and 22 seconds. In the micrographs shown in Fig. 2 the dots presented in figure (d) are more uniform and well filled than those on figure (c). This observation is confirmed by the curves in the Fig. 6.

The images (d), (e), and (f) of the Fig. 2 indicated the increase on the formation of little secondary dots from the thin film of ink on the silicon surface (lack of blade cleaning). The values of reflectance of the Fig. 6 indicated a decrease in the complete ink transfer to the glaze surface due to the increase in the ink flow difficulty, with an increase in the percentage of light reflected, and interpreted as a tendency of the curves towards higher values.

Analyzing the Fig. 3, from (a) to (f), it can be noticed that the ink transfer from the cylinder to the glaze has been damaged, and so, diminishes as the ink viscosity increases; although the defect due to lack of cleaning is partially covered by the higher volume of ink areas of 85% of the gray-scale, it still can be seen in a crescent way between the images (d), (e) and (f).

The decrease in the values of percentage of coverage area by decoration can also be verified in the data of Fig. 4, effect confirmed through the curves shown in Fig. 7. As the viscosity increases, it can be observed an increase in the percentage of reflected light, although exists more pigment proportionally, while the increase in density; in this case, the reflectance increases due to the same fail in the ink transfer from cylinder alveolus to the tile surface.

Fig. 7: Changing in reflectance values due to the increase of density and viscosity for the 85% of Gray-scale covering. 0,4/45° engraving.



In Fig. 8, Fig. 9 and Fig. 10 are shown, respectively, the micrographs of the decorated samples with 5%, 25% and 85% of the gray-scale. The Fig. 11 shows the graphic evolution of decorated area with the MTD 40/22° engraving as the density and viscosity increases. The micrographs of the Fig. 8 for the treated images, one can observe that the ink transfer increases and the shape of the dots began to seem more regular and more filled, confirmed by the data in Fig. 11.

In images (d) and (e) in Fig. 8 the same problem of lack of cleaning can be observed.

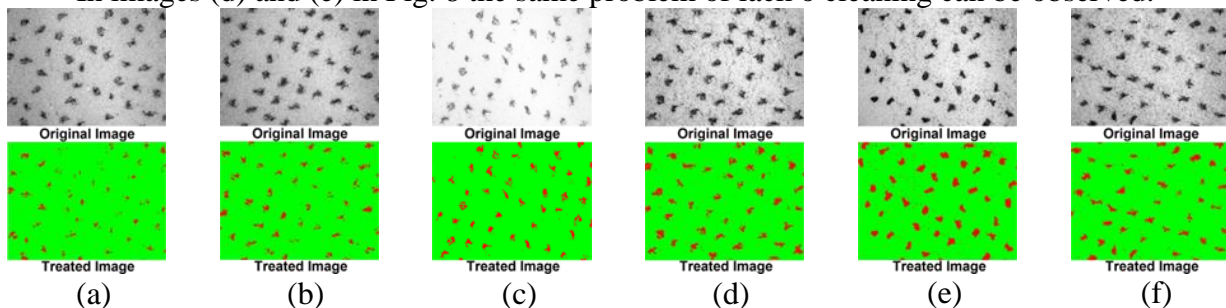


Fig. 8 – Decoration of 5% of Gray-scale with image analysis for the MTD40/22° engraving, with viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.

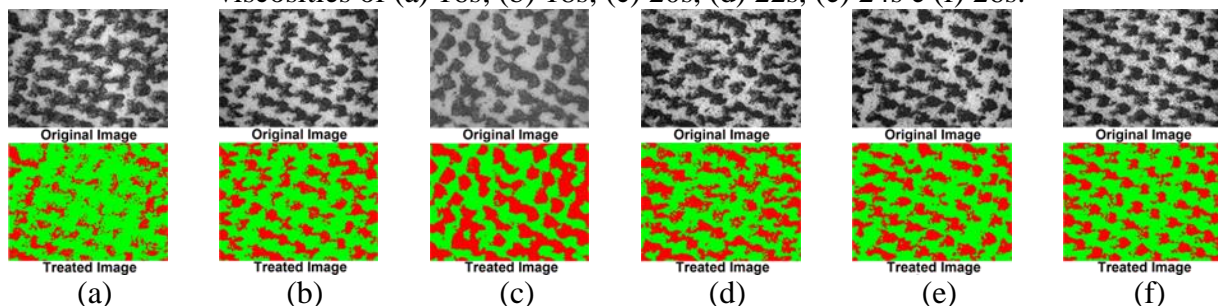


Fig. 9 – Decoration of 25% of Gray-scale with image analysis for the MTD40/22° engraving, with viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.

Confronting the analysis and the results shown above with the graphic presented in Fig. 12, it can be observed that the results are congruent, exception made on the 20s viscosity sample, which presented a value in reflectance out from expected. As the density and viscosity increases there is a decrease on the values of reflectance, in other words, there is an evolution regarding to the dot transfer from the cylinder alveolus to the glaze surface, which facilitates its filling.

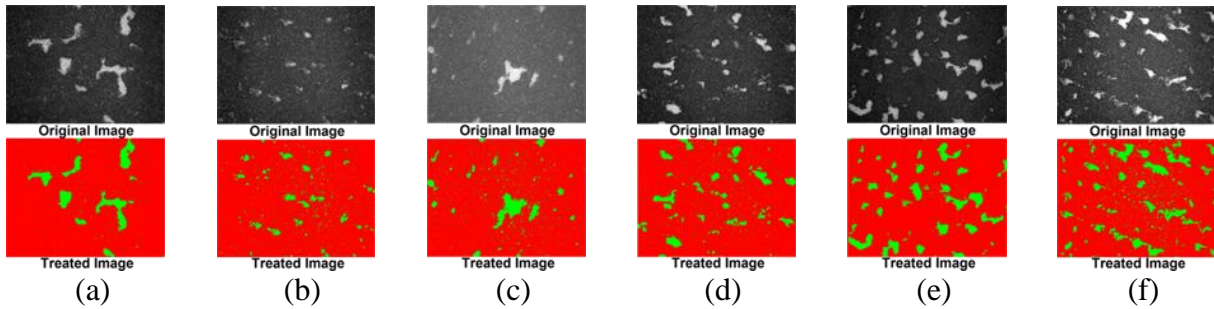
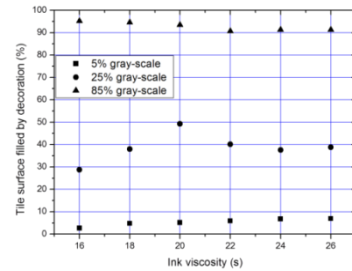


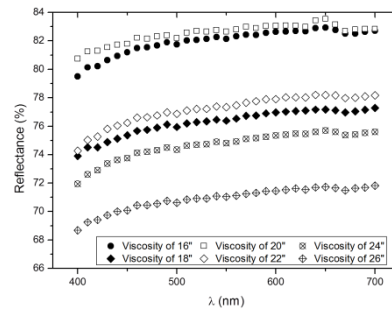
Fig. 10 – Decoration of 85% of Gray-scale with image analysis for the MTD40/22° engraving, with viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.

Fig. 11 – Decorated area recovering for the 5, 25 and 85% of Gary-scale areas for the MTD 40/22° engraving with the viscosities of (a) 16s; (b) 18s; (c) 20s, (d) 22s, (e) 24s e (f) 26s.



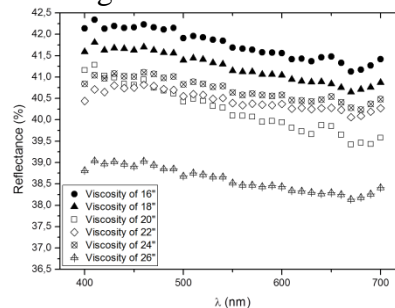
Comparing the images from (a) to (f) on Fig. 9, it can be said that the data presented in the Fig. 6 shown that in the beginning with the increase of the density and viscosity values, the ink flow from the cylinder to the tile gets better, and increasing even more the viscosity values, from the tests with the 20s viscosity ink, a decay on the efficiency of decorated dot filling occurs. This effect can also be confirmed by the analysis of the Fig. 13.

Fig. 12: Changing in reflectance values due to the increase of density and viscosity for the 5% of Gray-scale covering. MTD 40/22° engraving.



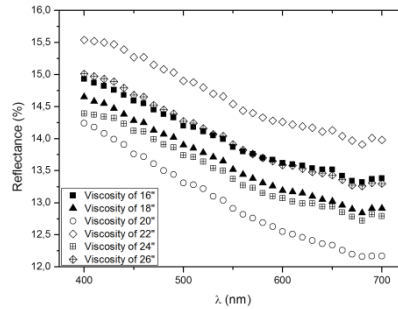
From the samples decorated with the 16s to the 20s ink there is a decrease in the percentage of reflected light by the decorated surface, which goes with the previous analysis presented. It can be noticed that the effect of cleaning failure by the steel blade became more important in this engraving, for the 25% of gray-scale decoration areas from a viscosity of 26s, which can be seeing through the less intense reflectance data on the graphic of Fig. 13.

Fig. 13: Changing in reflectance values due to the increase of density and viscosity for the 25% of Gray-scale covering. MTD 40/22° engraving



The image sequence from (a) to (f) of Fig. 10 shows that the decorated area diminishes. According to Fig. 11 this effect is slight, presenting little difference between the percentages of covered areas, as seeing in the Fig. 14 data. The expected reflectance for this variation in Fig. 14, as a result of the data presented in Fig. 11 should be an increase in the percentage of reflected light as the percentage of covered area by decoration decreases. In this range of values of gray-scale percentage, what is also observed is the strong coalescence of the decorated dots, this effect is worse comparing to the 0,4/45°. Probably, as a result of the dots characteristics; there can be a variation in the way how the ink flows out from the alveolus that favors some reologies over others.

Fig. 14: Changing in reflectance values due to the increase of density and viscosity for the 85% of Gray-scale covering. MTD 40/22° engraving



As an example the 20s viscosity ink shows a lower value of reflectance, indicating an inflection point, where the higher values on viscosity do not give the same area filling or an easy way to discharge all the solid part of the ink together with the liquid one.

Similar discussion can be made to the samples decorated with the 24s ink, which reflectance curves is a little above the curve for the 20s samples. Here, what explains this fact is that although the covered area percentage for the 24s sample be lower than that presented for the 20s samples, the relative percentage of pigment in the first one is higher than the second, which means that there is a higher concentration of colorant transferred to a surface that became less reflective. The decrease on the percentage of ink transferred from the alveolus to the tile is caused by the increase on the surface tension as the values of viscosity increases.

CONCLUSIONS

In both cases studied none of the engravings have shown the expected dot shape and filling. In the conditions chosen in this work, with changes in viscosity and density only using a regular medium, none of the engravings achieved the best conditions regarding to discharge the ink volume. It can be seeing that in both cases there is, in general, a maximum point achieved by the viscosity and density, which provides a better ink discharge and, consequently a better surface decoration.

Values too high of viscosity and density prejudice the right cleaning process accomplished by the steel blade, which leads to defects on the decoration process. The percentage of reflected light by the decorated surface is straightforwardly connected to the percentage of covered area by decoration. The rheological effect of the ink is more visible in the low and high hues of the gray-scale (5% and 85% respectively), as can be seeing in Fig. 5; 7; 12 and 14.

Independently of which way used to achieve the best viscosity and density, it is clear that the ceramic tile producers have to pay real attention during and between different batches on the process, controlling both ink density and viscosity which have great influence on the final overall hue. When chosen an specific image to be reproduced on ceramic tiles the designer have to pay attention on the overall gray-scale distribution over each image channel, with the intention to determine the best density and the best viscosity that will maximize the ink charge and discharge on the silicon engraved cylinder, which will provide a better dot formation and, consequently; a decoration within the quality standards determined by each producer.

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