THE CERAMIC DESIGN PROCESS ADAPTED TO DIGITAL PRINTING

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ABSTRACT

This paper seeks to describe an appropriate work flow that, together with the use of suitable tools, could raise the productivity of the ceramic manufacturing process.

The use of colour profiles, graphics treatment in PhotoShop, and image preparation for printing, as well as identification of the factors to be taken into account and of the tools to be used, are issues that, excepting the distance between the different machinery manufacturers, today form a common nexus between designers in the ceramic sector. These issues are addressed in this paper.

1. CONTEXT

The ceramic tile sector is in the midst of change owing to the incorporation of digital printing machines into production. The singularity of these printing machines and of the tile manufacturing process has altered the way in which the designs and patterns to be reproduced are treated by sector companies.

Terms like colour management, profiles and four-colour printing, which are proper to the traditional graphic arts sector, intermingle with expressions such as 'multi-channel', ceramic inks, base glazes, and kiln temperature, which are traditional terms in ceramics.

This mingling of two worlds of graphic decoration, so close yet so far apart, has given rise to the creation of new design methods and new colour management adapted to the ceramic sector. Examples of such changes are the use of colour profiles and a return to multi-channel design.

It is necessary to reconcile these traditional colour management techniques with the new design methods. New tools are used and new methods need to be adapted to appropriately implement this new technology, which has consolidated itself as a further form of ceramic tile decoration.

2. NEED FOR A NEW PRODUCT

New graphics and reused graphics: At present, based on the demands of ceramics manufacturers, two types of graphics are being adapted to digital printing. Thus, on the one hand, there are the so-called reused graphics, which relate to products fabricated by means of other, previous technologies, such as rotary or screen printing technologies.

These graphics, which in the best of cases are stored in digital files, were logically developed in terms of the possibilities of the particular technologies involved. For various reasons, companies may need to continue making these products, using ceramic digital printing technology. However, in order to be able to take this step, certain preparations are first needed.

A resolution used, such as 180 DPI, might be considered standard. However, technology at present allows and encourages the use of resolutions of 360 DPI and higher. This means that a point interpolation is required, which is not always performed correctly, and may lead to loss of definition and undesired effects.

In order to overcome this first hurdle, the graphic needs to be treated after its resolution change, either by means of filters that treat the pixels directly or by applying levels.

Another great problem that arises when it comes to using graphics from other technologies is that they are multi-channel and must, therefore, be converted into

RGB or CMYK colour spaces, which needs to be done correctly because otherwise there may be notable differences in the tones of the resulting colours.

In addition, these channels could have been of any possible ceramic colour, this being something that is currently not possible by digital printing, so that some original colours can probably not be reproduced. In this regard, there is at present no possible solution since it is impossible to reproduce colours outside the reproducible spectrum of the machines.

This issue may subsequently be solved as a result of the research into and development of new inks that are compatible with digital printheads: such purer inks, in colorimetric terms, could yield a greater range of reproducible colours.

3. IMAGE DIGITISATION

With regard to the new graphics, developed directly in terms of the technology to be used, given the resolution capability of these machines, the starting data must be of the highest possible quality. Therefore, high-performance digitisation mechanisms of the original need to be used.

A flat scanner is a good option when the original is not too big, but the originals and the resulting tiles tend, increasingly, to have extremely large sizes, so that this option loses ground compared to capture systems with CCD sensors. These new digital camera-based systems are usually expensive and may sometimes be useless, if very large originals need to be digitised and the digitisation mechanism is based upon the movement of the original and not on the capturing system.

At ITC it is sought to develop a user-friendly system for the digitisation of large sizes without the drawbacks of current systems, working at high resolutions and producing high-quality RAW files.

This system will allow non-contact digitisation and digitisation by parts of large surfaces without weight or length being a concern, thus making this a topical, prospective instrument for companies that make original graphics to use.

4. COLOUR MANAGEMENT

After the appearance of ceramic digital inkjet technology, colour management gradually became important and, subsequently, indispensable in any work flow.

First, calibration and profiling need to be performed of all elements involved in visualisation and colour production: digitisation tools (digital cameras or scanners), visualisation devices (computer screens), and the printing machines themselves:

- Input profiles, describing scanners and digital cameras.

- Screen profiles, describing LCD screens and monitors.
- Output profiles, describing printers and printing machines.

In order to control the variations of a particular device, the profiles must be kept up to date, since the performance of a device changes over time and that is when the device needs to be recalibrated. If, notwithstanding a recalibration, its initial performance cannot be reproduced, it needs to be re-profiled.

A device profile contains information on three principal variables that describe how the device performs:

1. Spectrum. Colour and brightness of the (primary) colorants.
2. Dynamic range. Colour and brightness of the white point and the black point.
3. Tone. Tone reproduction characteristics of the colorants.

Once the profiles have been created and installed, the work flow can be initiated in which, first, colour significance must be given to the files that are opened, assigning them the profile of the appropriate digitisation tool.

The next step is colour normalisation, transforming the image into an RGB working colour space. Independently of the space chosen, in a design department, all the units must have the same RGB working space in order to maintain consistency in the correction actions and thus allow collaborative work.

The colour spaces (profiles, essentially) must be more extensive than the target colour spaces in order to avoid colour losses. This is not always possible, though that should not be a reason for using RGB capture colour spaces as working colour spaces, since they are not uniform or designed for working.

All the applications that administer colour enable predetermined profiles to be established for RGB or CMYK, but if various applications are used, it is necessary to make sure that all applications use the same predetermined profiles. Based on our experience, we suggest Adobe RGB 1998 or Apple RGB as good working profiles, since they are extensive and have a good grey balance.

The selection of an appropriate interpretation approach for the graphics and the use of black point compensation assure that the black in the source will always have a black expression in the destination. This use of black point compensation can avoid the following problems:

- If the source has a lower black point than the destination black point, all the darker values in the source than in the destination will reduce the black, breaking up the detail in the shadows
- If the source has a higher black point than the black point in the destination, the converted colour will not contain true blacks, making the result look faded

5. FILE FORMATS, RAW DEVELOPMENT

One can start with camera-digitised originals with the possibility of obtaining RAW format images or use scanners, obtaining TIFF documents. The main difference between these formats is that the RAW image is a digital image file format that contains all the image data as captured by a camera's digital sensor. When shot in RAW, the camera performs no post-processing, since it only stores the information in memory.

When photographing in RAW, one has greater control of image appearance: it is possible to correct aspects such as exposure, white balance, contrast, saturation, and the calibration of the different colour channels, all without any information loss. In order to be able to make these adjustments, specific software is required to process the RAW files by means of digital development and to convert them into TIFF files for subsequent printing.

Knowledge of the morphology of the histogram is essential in order to be able to capture the image, as well as to develop and make the relevant adjustments for digital printing. First, one must start with a good tone distribution in the RAW capture.

A histogram illustrates in a graph how the image pixels are distributed and shows the quantity of pixels in each colour intensity level. The histogram indicates whether the image contains sufficient details in the shadows (on the left), halftones (in the middle) and illuminations (on the right) in order to perform a proper correction.

There is a very clear relationship between the form that a histogram adopts and image quality, so that all adjustments of the basic development need to be controlled in order to form an image histogram and achieve good image quality for printing. The output histogram should resemble a Gaussian bell-shaped curve; it should extend at least to the two ends, with less information at the ends than in the centre segment, always having black and white.

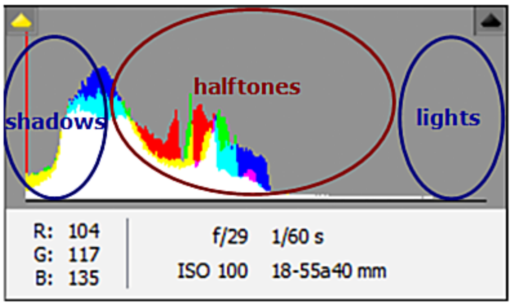

Figure 1 Histogram

Digital development begins by adjusting the basic parameters of light and colour:

1. Exposure: Adjusts the white point = White levels.
2. Recovery: Allows apparently burned highlights to be restored.
3. Blacks: Controls the black point = Black levels.
4. Brightness: Redistributes the information by clarifying or darkening the image without altering the black or white point.
5. Fill light: Illuminates the shadows respecting the black point.
6. Contrast: Adds contrast in the halftones without altering the white and black points.
7. White balance: Varies the image colour temperature and hue.

The development is continued with the most advanced clarity and intensity adjustments:

1. Tone curve palette: Allows performing fine adjustments in the histogram,
2. Clarity: With positive values it adds micro-contrast in the textured zones, provides volume, or enhances the image.
3. Intensity: Smart saturation, only affects colours with little saturation, especially protecting skin tones; this adjustment is equivalent to the Photoshop adjustment layer INTENSITY = 50
4. Saturation: Colour saturation in the entire image, this adjustment not being very recommendable.

RAW images development flow

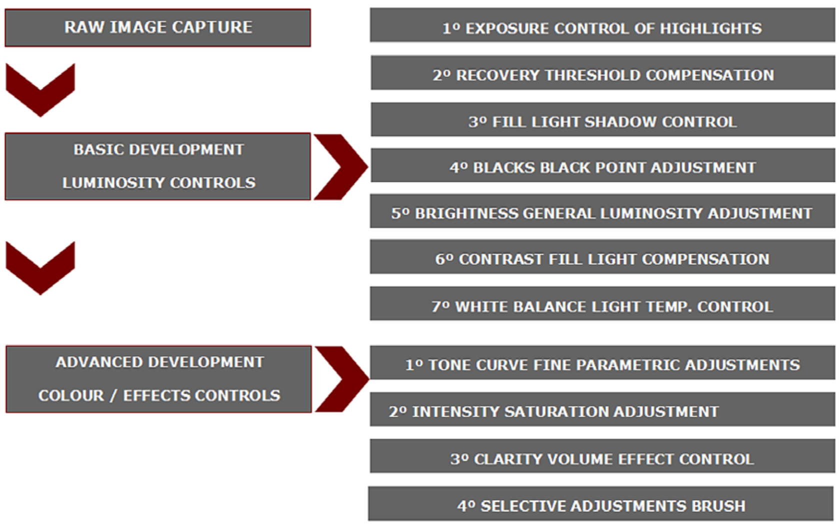

Figure 2 Images development flow

6. IMAGE PREPARATION FOR PRINTING

The final preparation of the image will depend on several factors, such as final destination, output size, image focus, and output profile.

Once the RAW image has been developed, it is saved as a TIFF file, the same file format as the images digitised by flat scanners. These files are used to start the adjustment treatment in PhotoShop, all image manipulations being performed by means of adjustment layers.

The tone intensities are modified by adjusting levels and curves. The important difference when it comes to choosing either of these is that the curves provide up to 14 control points for illumination, halftone, and shadow adjustments in individual channels, whereas the 'Levels' dialogue box only has three adjustments: white point, black point, and gamma. The curves are extremely useful for modifying the light in a tonal range without affecting the others or, in other words, when in a histogram it is sought to provide contrast without pushing the white and black ends. Another useful function of the 'Curves' dialogue box is also making precise adjustments in the individual colour channels of an image, it being possible to save the adjustments of the 'Curves' dialogue box as pre-set adjustments.

Using the tone–saturation control, corrections can be performed with adjustment layers to bring to the desired tone an image whose original tone has deviated after printing, or when different tones are being prepared for a ceramics series.

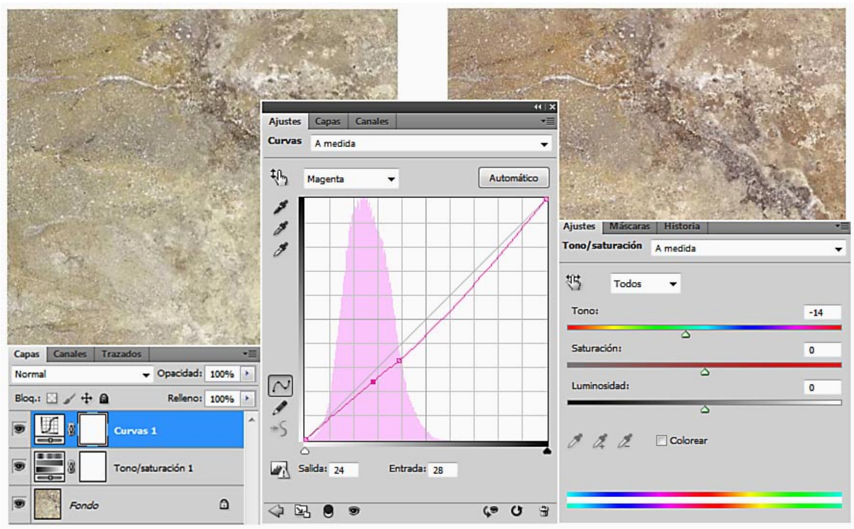

Figure 3. Curves and Tone saturation adjustment layers

The tone creation adjustments and graphics modifications are performed in this phase. The preview should be used to see what the piece is going to look like, thanks to the printing profiles, selecting the appropriate interpretation mode: relative colorimetric, absolute colorimetric, or perceptual so that the designers can preview what the graphics are roughly going to look like before proceeding with actual production.

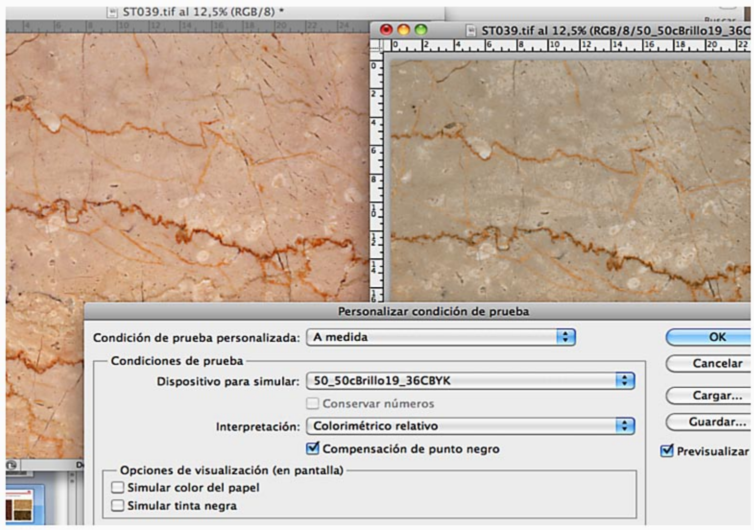

Figure 4. Image preview with the profile

Sometimes, depending on the characteristics of the image to be printed, as well as on the type of machine printheads, the injectors can give rise to lines in the print. In certain cases this is due to lack of continuous printhead feed, which produces a line owing to the absence of ink. In other cases, this occurs because very fine continuous patterns are to be printed on a grey scale, which generate the same drop size on printing aligned points of the same size, leading to the optical effect of a line.

It is therefore important to verify the channels that form the image, controlling the channels with very flat intensities as well as the channels with much colour intensity, since corrections will need to be made to avoid such problems. The corrections usually consist of clarifying, decreasing the intensity of the channels or affected zones, and even generating noise with a certain defocusing in the case of very flat patterns.

7. FILE MANAGEMENT

When the modifications have been accepted, the images are stored in files with non-destructive colour information formats, such as TIFF or PSD (Adobe PhotoShop© proprietary tile format), the latter being the best option if adjustments have been made by layers. It is not good practice to save graphics in JPG files, even when the maximum quality configuration is set, since there will always be precision losses in the colours stored owing to the algorithms used in image compression.

Subsequently, in order to be able to send the file for printing, the image is converted from the RGB to the CMYK mode of the machine's printing profile, generating a CMYK file that is saved in the TIFF format, connecting layers if there are any and thus leaving it ready for the printing trials.

It is advisable to revise the image resulting from the profile colour conversion in order to make sure that each channel has the intensities required by the printing machine, and to be able to avoid printing failures caused by the image.

8. VALIDATION OF THE PRINTED IMAGE

Once the graphic has been printed, it needs to be checked to make sure it is correct or whether, instead, it is unsuitable for final production. In this phase, it is evaluated whether the reproduction of the tones is satisfactory and, should this not be the case, the necessary tone adjustments will need to be performed again to correct the deviations.

Should lines appear in the decoration owing to an inappropriate graphics design approach, it is necessary to return to the design phase and modify the image channels that are too flat and can produce these errors in the machine.

9. WORK FLOW SCHEME

Figure 5. Work flow scheme.

10. IMPROVEMENTS IN MACHINE EFFICIENCY, LINEARISATION

Linearisation consists of modifying machine performance, such that the true density of the printed points coincides with pixel density in the digital channel. That is, if the command is sent to print a yellow channel density of 20%, 20% must be actually printed on the tile, no more and no less.

In order to verify the state of a machine in this regard, trials need to be conducted and the graphics need to be measured to view the gain curves of each channel; these results are directly linked to the base used, the resolution, and the firing temperature.

The following study has been performed at ITC, using an INKJET printing plotter, with four inks: cyan, yellow, magenta, and brown. The generated study control image prints patches of the four channels at two percentage-point intervals.

By printing this test chart without any type of profile modification and firing the print at the set temperature, one obtains a ceramic piece that is ready for the density readings.

Once the densities of the different channels have been read, the gain curves per channel are obtained. These curves need to be compensated by their corresponding counter curves in order to 'linearise' the printing and achieve appropriate printing at each density.

In order to calculate the counter curves, a software was developed that reads the data provided by a spectrophotometer (eye-one Pro); it performs the relevant calculations and converts them into '.acv' type files, which plot the correction curves that can be applied in the design phase using PhotoShop.

During the initial trials, it was observed that the software results could be improved by means of a fine manual adjustment of the counter curves, thus yielding better results. At the time this paper is being written, a new version of the software is being developed that provides a better automatic result.

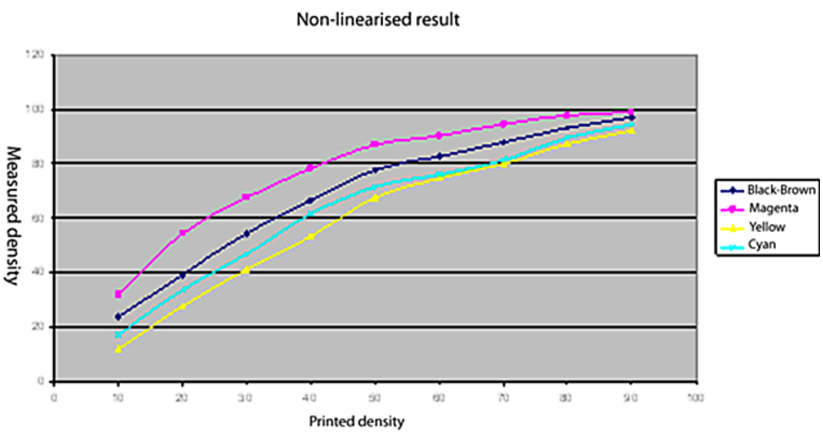

Figure 6. Non-linearised printing results.

As may be observed, in non-linearised printing (Fig 6), there is a difference between the printed density and the (real) measured density, which produces a loss of average values, increased ink consumption, and a possible lower 'maximum ink' accepted by the substrate.

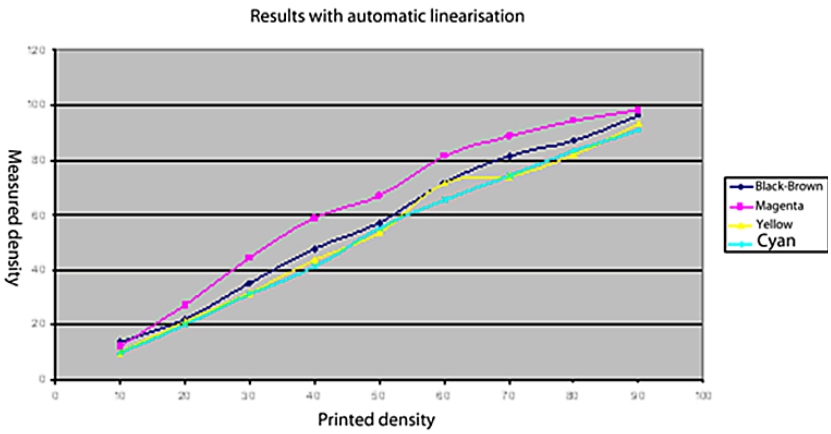

Figure 7. Printing results with automatic linearisation.

The results in Figure 7 show an improvement in the relationship between the printed density and the measured density. This improvement was achieved by applying the correction counter curves automatically generated by the software to the design.

The greatest correction was made in the magenta channel, since this was an ink that 'expanded' and had a high yield, so that it was necessary to control it more closely.

In addition, as may be observed, it was not necessary to print up to one hundred per cent density in magenta in order to obtain a maximum density measurement, so that more of this ink did not need not to be printed, with the ensuing saving.

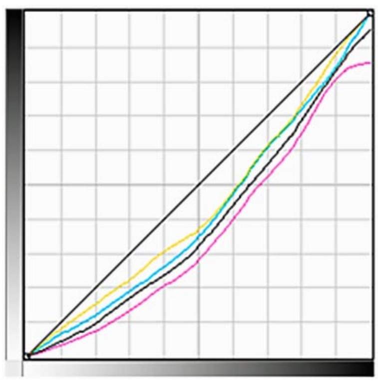

Figure 8. Automatic counter curve.

It was possible to improve upon these good results by manually adjusting the counter curves, based on the automatically obtained results.

Figure 9 shows the counter curves resulting from the consecutive automatic and manual processes.

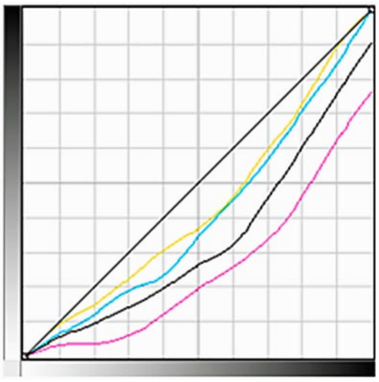

Figure 9. Refined counter curve.

Figure 10 depicts the values obtained in printing with the applied curves.

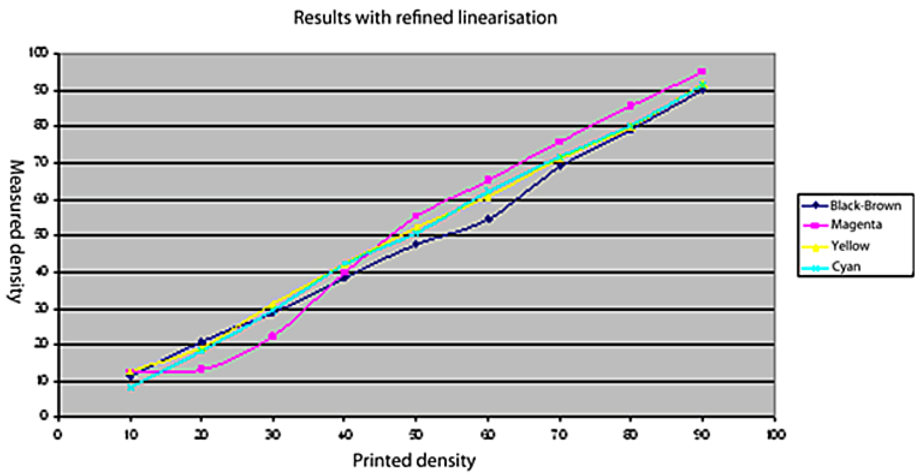

Figure 10 Results obtained with the manually refined counter curve.

11. CONCLUSIONS

Many factors can affect tone reproduction of the developed graphics, ranging from the yield of the inks used, interaction with the base glaze, firing temperature, and printing resolution. All these factors need be to taken into account in developing appropriate profiles for each situation and applying them correctly in the design phase.

The paper presents the results of printing curve linearisation using devoted software.

The fact that four-colour printing is being simulated when the inks do not represent the actual primary colours (cyan, magenta, yellow, and black) poses a series of problems when colour management is directly transferred, without any preliminary adaptation, to the ceramic sector. Work is currently on-going in this sense, creating profiles not just for four-colour printing, but also for multi-channel printing with the colours that are actually used.

ACKNOWLEDGEMENTS

The authors wish to thank the manufacturers of ceramic digital printers such as Durst, S.A., and Cretaprint, S.L., for the support provided, and they also thank IMPIVA and the European Fund for Regional Development (EFRD) for their financial support.

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