EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT INKJET PRINTING IMAGE CONTROL... BUT WERE AFRAID TO ASK

J.P. Peset [(2)], J. Plasencia [(2)], J. Clausell [(1)], L. Ortiz [(1)]

[(1)] Instituto de Tecnología Cerámica (ITC). Asociación de Investigación de las Industrias Cerámicas (AICE). Universitat Jaume I. Castellón. Spain

[(2)] Departamento de Ciencias de la Comunicación, Facultad de Ciencias Humanas y Sociales. Universitat Jaume I. Castellón. Spain

ABSTRACT

This presentation aims to clarify a series of questions and points regarding the overall image preparation and tonal adjustment process for ceramic digital printing.

The photographic image has emerged as the child prodigy of this new era. Understanding and experimenting with the digital nature of the photographic image have become top production needs. The successful or precarious outcome of a complex digital process is reflected in the printed material.

From its origins, the conception and design of the image, to the visual effect perceived by the client lies a chain of interrelated digital processes. A comprehensive vision, detailed yet all-encompassing, will not only allow anomalies to be detected in the production chain, but it will also enable the best performance to be achieved in each of its links and, hence, provide a great variety of production benefits.

Proper process control incorporates benefits, and it enables integration of a methodology based on a criterion of excellence, quality, and efficiency, which is certain to translate into economic benefits.

1. CONTEXT

The digital era has become a deeply rooted reality in all societal communication and production processes. In the ceramic tile sector, the incorporation of digital printing machines in tile production has changed the conception of the image, image treatment, colour management, colour, and the workflow to printing, firing, and the exposition of results.

The new printing technology, together with the possibilities of image capture and postproduction, will afford boundless creative possibilities based on the capacity to reproduce, represent, or modify any real or imaginary element or scenario that can be printed on a ceramic substrate: textures, light effects, materials, fluids, landscapes, macrophotography, etc. There are further all the possibilities of printing on demand, which facilitate short production runs for exclusive designs.

2. WHY DON'T PHOTOS ALWAYS LOOK LIKE WHAT WE SEE? DO OUR EYES PERHAPS DECEIVE US?

Photography is a way of representing reality, a medium bounded by its own nature. The three conditioning factors that affect this process may be summed up as follows:

1. The physiology of vision: how does the eye see?
2. The mechanism of perception, the "visual culture" and its references:

   How do we perceive reality?
3. The technology of photographic reproduction media:

   How does photography reproduce reality?

Photographic capture involves the interpretation of reality in the form of an image. This process has limitations that we need to understand in order to achieve the most faithful possible representation.

For example, in regard to colour vision and the brightness of the scene, the eye works as follows: the retina, the physiological "sensor" charged with retaining the image that forms at the back of the eye, consists of two types of cells. There are the rods (which handle the variations in luminance intensity of the scene) and the cones (cells that specialise in colour vision). The eye uses three types of receivers that are sensitive to the three great spectral regions: red, green, and violet–blue. The analysis principle of RGB-based additive colour synthesis is involved.

Basically, the working principle of digital camera sensors is comparable to that of the human retina: a matrix of small photosensitive elements (pixels) evenly distributed through red, green, and blue filters – again the RGB additive synthesis principle – and an analog-to-digital converter able to proportionally convert the electric pulses of each pixel to digital information translated into a binary code.

However, even though both image-capturing methods are based on similar principles, many factors affect this interpretative reproduction process:

- Binocular vision and the three-dimensional effect.
- The eye's ability to adapt to different environmental conditions.
- The eye's visual sharpness and separating power.
- The perception mechanisms with respect to image colour, shape, texture, and tone.
- The angle of view, focus, and depth of field.
- The absence of "complementary sensations" (touch, hearing) that enrich the real visual experience.

For these primary and other, secondary reasons, the process reveals itself as a complex one and its technical control depends on an optimum photographic representation of the real scene for use in ceramic printing.

3. HOW AND WHERE CAN WE OBTAIN OPTIMUM IMAGES FOR CERAMIC DECORATION?

Generally speaking, there are three principal methods of obtaining digital images:

1. Direct capture by a camera or digital back-up.
2. Sequential photography by scanning.
3. Photographic galleries and image banks.

The first method is the most complex, but it is also the method that provides better technical control of the image and greater creative possibilities. Direct capture enables images of all types of materials, phenomena, and real three-dimensional objects to be obtained: a boundless world of creative possibilities and of customisation in ceramic decoration.

For optimum control of the capture processes, the following issues need to be addressed:

1. Quality standards shall be established of the equipment proportional to the results it is sought to achieve. The configuration of the image capture equipment, particularly the type and class of camera, the lenses, and all the system accessories, need to be considered here.
2. Workflow and colour management need to be watched and controlled from the outset, performing camera colour profiles and calibrations.
3. Careful attention shall be paid to quality control throughout the process: optics, sharpness and resolution control, file formats and capture, colour space, dynamic range and depth of colour, etc.

4. Lighting conditions shall be controlled and the colour richness of the scene shall be evaluated. The photography of materials, textures, atmospheres, etc. often requires the use of special artificial lighting techniques – grazing, diffuse, or polarised light – as well as accurate photometric adjustment.

The second method is appropriate for reproducing texture-free, two-dimensional originals. This point is important because there are technical proposals for the reproduction of 3D objects based on combining a camera and a lighting system on a fixed or moving support. Sequential photography by scanning – involving so-called scanners – consists of reproducing an original image by linear sensor scanning. This method is characterised by two features: first, it requires a "long exposure time" and, secondly, the single, diffuse, front illumination makes the method unfeasible for materials with irregular surfaces, gloss, or texture.

Finally, another widespread method of obtaining images is the use of images that are already available. Here there is an extensive offer, ranging from general image search engines in Internet to specialised image banks, including sites devoted to the dissemination of images free of rights. In our view, in this case, it is vital not only to pay careful attention to the visual quality of the images, but in particular to their technical quality. Independently of the origin of an image, the following information on the image is needed in order to be able to establish an appropriate quality criterion for the final print destination. The parameters involved are as follows:

1. File size, dimensions.
2. Image format – RAW, DNG, TIFF, JEPG, etc.
3. Complementary metadata: camera, lens, ISO, WB, bit depth, colour profile, colour mode, etc. Images that are downloaded from the Internet do not usua-lly contain this information, which might appear of little significance. However, the metadata of a digital file are the DNA of an image. These data allow the conditions in which the image was recorded to be identified and, hence, enable maximum control of the quality chain that we establish for our workflow.

4. WHAT PHOTOGRAPHIC CHARACTERISTIC MUST I CONSIDER IN DIGITAL IMAGES WITH REGARD TO QUALITY?

As on every journey, there's a starting point and a destination. If we don't know where we started out from or where we're going, it's impossible to plan the trip. In order to be able to establish a workflow that matches the intended result in the final print, one first needs to know the starting conditions. In the digital image, these parameters consist of more than just image resolution or file format. A brief guide is set out below on the most important characteristics.

Objectives and measurable features		
	What is it?	How is it measured?
Image size	Total image size, resolution by total dimensions.	In pixels e.g.: 2832 x 4256 px

Resolution	Image size per unit surface area.	In pixels per inch e.g.: 300 ppi
File size	Image size by depth of colour.	Megabytes (Mb) Gigabytes (Gb)
Format	The image saving or compressing method.	RAW-DNG-JPEG-TIFF
Depth of colour	Levels of grey for each channel.	In Bits: 8 Bit, 16 Bit, 32 Bit, 64 Bit...
Colour mode	Quantity of colour data that a graphic file can store.	sRGB-RGB-Adobe RGB

For subjective evaluation			
	What is it?	How is it recognised?	How can it be avoided?
Noise	Random variation of brightness or colour in a capture device.	Grainy appearance of the image.	Reducing the ISO index during capture. Specific noise-reducing software.
Density	Light absorption ability in a photographic image.	Evaluating the darkest zones.	Controlling image lighting and processing.
Contrast	Difference between lights and shades.	Colloquially known as high contrast or low contrast images.	Controlling image lighting and processing.
Sharpness	Absence of blurring.	Loss of detail, usually caused by defocus or a moved photo, though there are many other causes.	Controlling focus and trepidation during capture.

Random defects			
	What is it?	How is it recognised?	How can it be avoided
Optical aberrations	Defects and own limitations of the lenses: distortion, chromatic aberration, vignetting, spherical aberration, coma, astigmatism, etc.	Image deformation, separation of primary colours, lack of uniformity in the exposure, etc.	Optimising the optics, diaphragming, and in some cases using devoted software.
Compression artefacts	A noticeable distortion proper to the file compression methods, particularly JPEG.	Loss of definition and detail, particularly at the edges.	Avoiding compression and using certain post-processing programs.
Sensor defects	Moiré, aliasing, blooming, etc.		

5. IS MY WORKFLOW OPTIMISED?

The new work approaches require understanding not just one, but several digital production and work software programs or tools:

Adjustment and digital editing software, RAW development modules, colour conversion engines or specific RIPs, as well as the additional plugins and scripts or complements that can enhance image finish and flow. And this is even more so if we analyse the constant convergence by the multinationals in software suites or compact, interrelated work modules. This, logically, opens up a multitude of routes and options for the same workflow or production process, which sometimes hardly display any substantial differences in the obtainment of the business product.

Within the ideal environment of a work process, there are different developmental phases. First, in-depth knowledge is required of the operation of the different digital tools or software programs, though this initially entails analysing processes that we may feel are of little practical use for optimum work. In the second place, logically, we must identify all those elements that are redundant or unnecessary for our daily work needs, using that acquired thorough knowledge of the tool. And finally, from the standpoint of prior knowledge and the constant upgrading and learning that will enable us to keep a linear, equitable evolution with the work tools or software programs, to learn the different methods of non-destructive automated functions that will enable us, ultimately, to materialise our proper workflow in concrete savings in time and money for our business product.

With regard to the above-mentioned business convergence of the software in one or two big companies, in our view a single software program will be unable to execute, in the best possible way, each of the different work processes with a view to occupational and economic efficiency.

6. WHY SHOULDN'T I WORK THE DIGITAL IMAGE IN THE CMYK MODE?

RGB images use the three primary colours of light to reproduce on screen up to 16.7 million colours.

The RGB model assigns a value of intensity to each pixel ranging from 0 (black) to 255 (white) for each RGB component of a colour image. For example, a bright green colour could have an R value of 17, a G value of 246, and a B value of 6. The brightest attainable green is R: 0, G: 255, B: 0. When the RGB values are identical, a grey tone is obtained, the lightness of which will vary as a function of the intensity. If each channel has a value of 255, the result will be pure white, whereas it will be pure black if all components have a value of 0.

The CMYK model is based on the ability of objects to absorb and reflect light. If an object is red, this means that it absorbs all the visible light wavelengths except the red component. The subtractive (CMY) and the additive (RGB) colours are complementary colours. Each pair of subtractive colours creates an additive colour and vice versa.

In the CMYK mode of Photoshop, each pixel is assigned a percentage value for the four-colour printing inks. The clearest colours (light colours) have a small percentage of ink, whereas the darkest (shades) have larger percentages. For example, a bright red might have 2% cyan, 93% magenta, 90% yellow, and finally 0% black. In CMYK images, pure white is produced when the four components have values of 0%.

Having understood the basic, structural issues of each system, we realise that the CMYK model is based on colour subtraction through the reflected light. In contrast, the RGB system synthesises its nature by summing the lights and their consequent joint projection.

Any digital monitor, LCD screen, or image projection system is, logically, based on the RGB components and colour system. Therefore, the logical and necessary process to obtain the most faithful possible match to the original colouring of the digital image starts with the need to keep that model or work space consistent across the different devices. Therefore, any process that requires visualisation of a digital projection must be linked to an RGB space, while for an optimum finish any ink printing system will need a digital system based on its own subtractive nature.

In addition, image-editing software program possibilities are limited by using a work space in the CMYK mode.

7. DO WE NEED TO KEEP A DESTRUCTIVE PROCESS IN OUR WORKFLOW?

From the digital beginnings, work software has developed according to the guidelines and business needs of big companies. This has meant a constant, growing, variegated tumult in the different accessories, peripherals, and elements or tools proper to the work software.

The progressive disappearance and absorption of the software by the multinationals and the need to make the work processes profitable are resulting, within a wide range of formats and work options, in a single concept that enjoys a general consensus: the non-destructive process.

The PhotoShop tool is perhaps one of the few software programs that still keep a destructive nature in the normal execution of the internal work. The rapid development of computer and digital elements are certain to lead to changes towards a much cleaner and more consistent concept in the treatment of the original files. At present, together with the multitude of possibilities and options that the digital image-editing software par excellence has, it is necessary to learn how to differentiate between destructive and non-destructive processes, in order to meticulously correct any feature of our digital file. The only ensuing major problem lies in the need for greater disk capacity than is currently required by a non-destructive digital editing system.

This all becomes very special and meaningful in colour management because the ability or need to modify or update a previously processed file is a logical, common production work process.

8. WHAT IS THE MOST APPROPRIATE COMBINATION OF INKS FOR MY CERAMIC PRODUCTION?

When we decide to incorporate a ceramic digital printing machine into the company, we must determine the colour gamut needed to be able to continue producing the same type of product. That is, we need to determine the tones in which current company production lies in order to be able to study which combination of inks is most suitable for reproducing this range of tones.

The original inks are C M Y K. The farther we move away from these, or from the relationship that they have to each other, the more difficult does the reproduction of the images become. Assuming that it is necessary to decide.

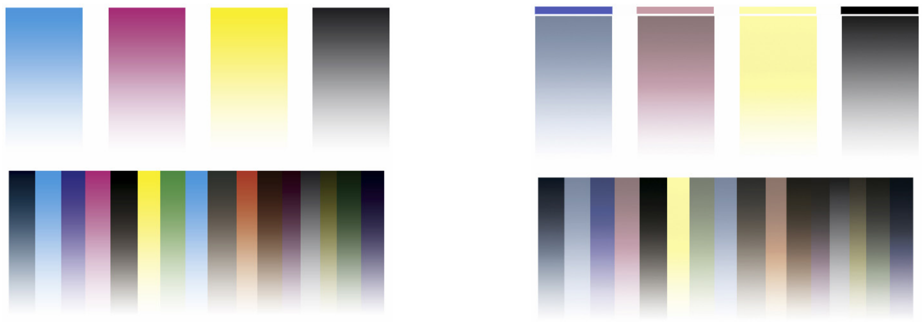

Figure 1. Comparative analysis of the colour combination between Standard CMYK and a combination of ceramic inks.

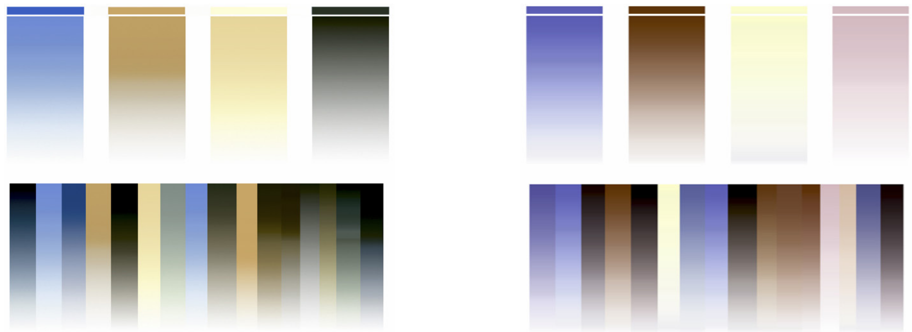

Figure 2. Colour combinations with black and without black.

The printing processes designed to obtain a given colour gamut by mixing several inks are based on combining these inks in percentages up to 100% of the different primary inks, combining various ink quantities to reproduce a printed image that simulates the continuous-tone feel of a photographic image.

Combining different percentages of the primary inks enables millions of colours to be reproduced, it being theoretically possible to combine 100% of each primary ink, which might involve 400% ink input in four-colour printing systems (CMYK)

However, this optimum situation does not occur in reality because the pigments are not completely pure and, consequently, are unable to absorb all the light, which produces the feel of a dark brown instead of a black; this entails a reduction in the printing colour field with cyan, magenta, and yellow. This shortcoming is corrected by using a fourth ink, black, in those areas where the image is black, dark, or contains grey, thus offsetting the lack of colour saturation.

Black is generated as a function of the grey component, i.e. those areas of the image where the three CMY inks act simultaneously. The incorporation of the black ink in printing helps reduce printing costs, if we replace these parts of the CMY image (the areas where cyan, magenta, and yellow act at the same time) with a percentage of black. This percentage is determined by the smallest percentages of the CMY inks. This has led to the concept of skeleton black.

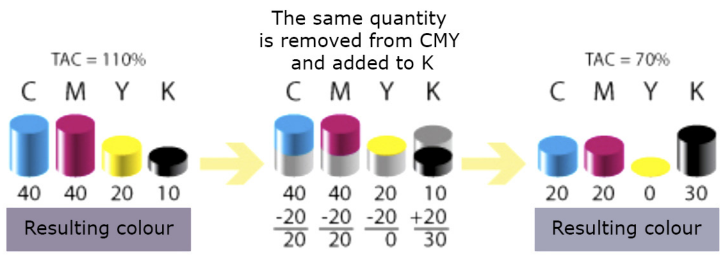

Figure 3. Visual scheme of the reduction in ink consumption on using black ink.

9. IS MY COLOUR PROFILE ETERNAL?

An ICC profile is a data file that mathematically describes how a device reproduces colour. In ceramic inkjet printing, a table of numerical values is involved that displays the coordinates of any colour that can be created as a result of combining three components: a certain combination of inks, a ceramic glaze as printing substrate, and a kiln curve in which this is all fused.

These colour values are read by means of a spectrophotometer (RGB colour mode) on a printed ceramic (CMYK mode). They are then converted to numerical tables of the coordinates of the LAB mode diagram in order thus to be able to identify the colours and their correspondences in the different colour spaces.

In ceramics, the different conditioning factors that arise are well known and, however small they may be, they can cause the end tone of the piece to vary. It is therefore vital to test any change that may occur, whether owing to a change in glaze composition, variation by some tenths in the ink printhead temperature, or even in the kiln curve.

Profiles must be controlled, and monitors vary with time, as do printers with use and maintenance adjustments. All the devices to be used in the ceramic digital printing process must be stabilised and optimised within their own conditions or limitations, antiquity, lighting, temperature, humidity, environment, etc.

10. WHEN AND WHY DO I CONVERT MY IMAGE TO CMYK WITH ITS CERAMIC PROFILE?

The foregoing has outlined that the RGB colour mode is a colour space for working the image, while the CMYK colour mode is a colour mode designed for printing the images, but not for working with them. The conversion to this colour mode is the pre-printing step.

Thanks to the profile, working an image in RGB and previewing it in CMYK allows the best possible colour conversion to be found for achieving the desired effect. If the image is modified directly in the printer profile (CMYK), the conversion is lost and the descriptive nature of these profiles can thus produce unwanted effects. As they are not profiles created for designing, they can contain colour deviations.

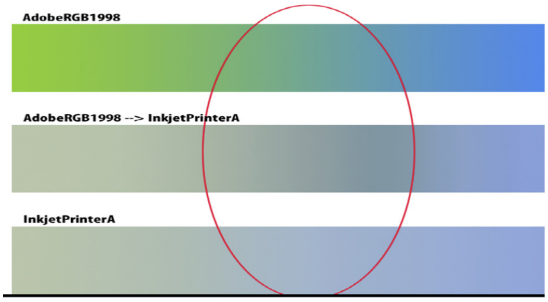

Figure 4. Comparison of: (top) the creation of a gradation from the RGB space; (centre) the RGB space with visualisation of the output profile; and (bottom) conversion from the CMYK image to the output profile.

In any event, the selection of a good working RGB is essential. Standard working RGBs are available, such as AdobeRGB, AppleRGB, or sRGB, but these colour spaces are too large compared with the ceramic target space.

If a single dimension of values is taken (e.g. the red channel), it can be observed, as noted previously, that 256 different values (intensities) can be assigned for this channel. If the image in RGB is modified, visualising it in ceramic CMYK could lead to an unwanted effect, namely excessive colour jumps while the image is adjusted.

This is because the same number of possible levels includes a greater or lesser Lab colour space.

A jump of one point in a large colour space (AdobeRGB) means a jump of more points in the previewed (target) space.

Assigning reinterprets the RGB or the CMYK values. This is used to visualise the appearance of the colours in another colour space of the same type: RGB in RGB or CMYK in another CMYK, but never between different colour modes. To do that we can use the preview and convert at the end, which does in fact modify the values.

- The profiles do not correct – they transform. They are not a calibration.
- The profiles do not eliminate the need to calibrate, linearisation.
- Implementing them only enables colour to be controlled.

11. WHY CAN'T I WORK AT 180 PPI WHEN THE RIP PREPARES IMAGES AT 360 PPI?

The image that we wish to transfer to a ceramic piece sets out on its path in a scanner, a camera, or in any digitisation device, and this is when we must consider the output resolution in order to perform the capture with the same resolution and thus avoid transformations.

The incorporation of these fabulous printing machines, which facilitate the printing of large-sized images, causes the work files to contain ever more information as the resolution increases. It is therefore often decided to work the image in a comfortable way, at 180 ppi, with images that do not have much weight and leave the responsibility of the transformation into printing resolution to the machine RIP. It is certainly true that printing machines are increasingly better equipped, and in this case some come with sophisticated RIPs with interpolation programs, but this does not mean that there will be no surprises with certain models generated with images that have a very fine pattern and gentle gradations.

Dot gain?

In ceramic digital printing, greater dot gain can be obtained by controlling the factors that affect ink performance and the printing substrate. Consequently, it is important to calibrate the intensity percentages between the digital image and the printed image. linearisation of the machine.

Factors influencing dot gain include:

- Ink, viscosity, density, and temperature conditions…
- Glaze surface conditions.
- Printing speed, resolution used.
- Injector height with relation to the substrate.
- Injector voltage.

12. CONCLUSIONS

This paper has attempted to provide a brief answer to the most common and important question raised by those starting to use images for ceramic printing. Most questions are based on erroneous assumptions that lead to grave consequences in the workflow.

By way of summary and conclusion, we should like to highlight two ideas:

1. The workflow is a process that starts with the visual interpretation of the scene and ends with the visual reception of the printed piece. There are three basic stages in this process: image acquisition, image processing and preparation, and printing. Each and every one of these is important, and they are needed to control the final result.

2. We start out from the greatest colour space: that of human vision, and we end up in a very small space: the CMYK space for ceramic printing. Colour loss will necessarily occur along the way, but appropriate colour management enables the result to be adapted to finally allow vision to interpret a similar effect.

REFERENCES

[1] Mellado, J.M. (2013): Fotografía de alta calidad: las técnicas y métodos definitivos. CS6. Anaya multimedia. Madrid.

[2] Bouillot, René (2005): Curso de fotografía digital. Omega. Barcelona.

[3] Rosso, Bernal (2003): Técnicas de iluminación en fotografía y cinematografía. Omega. Barcelona.

[4] Langford, Michel (2004): La fotografía paso a paso: Un curso completo. Tursen-Hermann Blume.

[5] Langford, Michael (2009): Tratado de fotografía. Omega. Barcelona.

[6] Frank, Mikkel (2006): Gestión del color. PC-Cuadernos Técnicos.

[7] Bruce Fraiser, Chris Murphy, Fred Bunting (2003): Uso y administración del color. Publisher: Anaya Multimedia-Anaya Interactiva.

[8] Mark D. Fairchild (2005): Color Appearance Models. Wiley.

[9] Erik Reinhard, Erum Arif Khan, Ahmet Oguz Akyüz, Garrett M. Johnson (2008): Color Imaging, Fundamentals and Applications. Publisher: A.K. Peters, Ltd.