Decoration of enamelled surfaces based on inkjet technology

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Introduction

Decoration of enamelled surfaces is widely used in the following application fields:

- Architectural panels.
- Signage and advertising panels.
- Pots and pans.
- Hobs and oven front controls.

Application technologies currently in use in porcelain enamel field are the following:

a) ***Screen printing:*** is the system mostly used at the moment. On steel enamel the application is done on fired enamel, while on aluminium enamel the application is done on fired enamel or on dry enamel ("biscuit"). The printed piece has to be fired again. Per each colour of each image is necessary a specific serigraphic frame. The application of more than one color is made sequentially and require the drying of the previous printing prior to application of the next. The decoration of large surfaces is often subject to the occurrence of surface defects due to the application or to the piece firing. It's not possible to make complex images or color shades.

b) ***Decals:*** inks used for the production of decals are manufactured using specific frits compatible with porcelain enamel firing conditions. With this method we can obtain complex images with a relatively wide range of colors. They are always applied on fired enamel and need a further firing of the piece. Can be adapted to non-flat surfaces. The bigger limit to their diffusion is that the application is normally made manually.

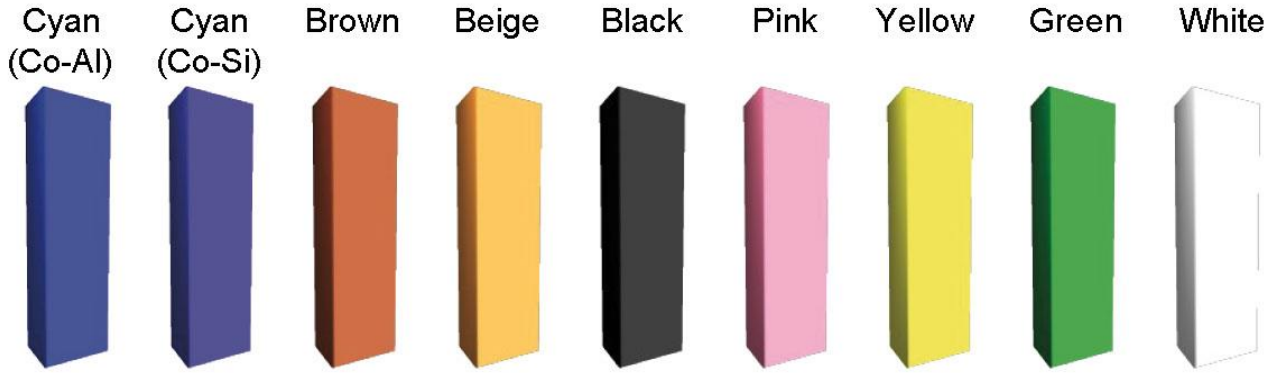
c) ***Padprinting:*** this technique has a small diffusion and is limited to small pictures. The decorated piece has to be fired again. Per each colour of each image is necessary a specific pad. The application of more than one color is made sequentially and require the drying of the previous printing prior to application of the next. It's not possible to make complex images or color shades.

d) ***Others:*** other decoration techniques, theoretically feasible, such as curtain coating, rotogravure, etc, are practically not used in porcelain enamel field.

All the up mentioned technologies have their limit in requiring an additional firing of the decoration, limited productivity and thus a relatively high cost, poor flexibility and does not allow the production of complex images.

Since few years the ceramic industry changed considerably due to the introduction of the inkjet digital printing. The printing is made on dry ceramic enamel through a specific inkjet printer. After decor application the ceramic piece is fired only once, in the simplest case. With this method is possible to obtain several aesthetic effects in an easy, quick and cheap way.
Over the time ceramic glaze producers set up specific inks for this type of technology. At the beginning it was proposed a four color inks combination using Cyan, Brown, Yellow and Black. Brown replaces sometimes Magenta or Black in certain applications. Black is inserted because it allows considerable savings in terms of consumption of the other three colors and a more precise regulation of their clarity. To expand the colorimetric range, rather limited in the case of four colors, other inks such as Green, Beige and Pink have been taken into account. In ceramic field special inks (White, Matt, Silver and Gold) allowing the development of different effects are taken into account (**Picture 1**).

Picture 1: available inks in Colorobbia Cinks offer.



Starting from the big success of digital printing in the ceramic industry, it was explored the possible application of the same technology to the porcelain enamel with the aim to remove limitations of existing technologies, reduce costs and increase the flexibility of the decoration process.

Digital printing: principles

The working principle of digital printing is based on the projection of equal (if we adopt a binary system) or variable (if we adopt a grey scale system) ink drops onto a rough or porous surface that allow their positioning in an univocal way.

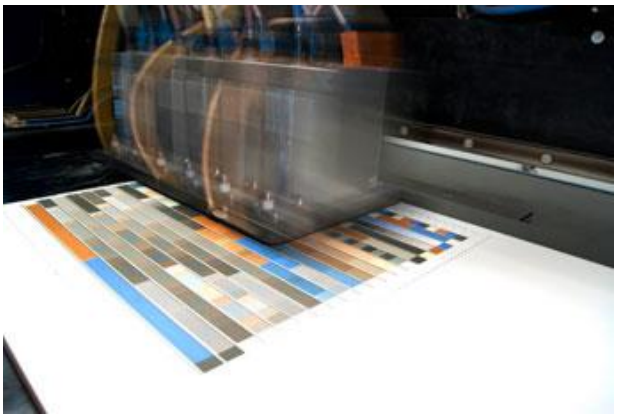
The rough or porous surface is normally represented by dry ceramic or porcelain enamel. Under study also products that once sprayed on fired enamel surface increase the surface roughness/porosity allowing the ink application of fired enamel.

The ink is made by a an organic vehicle and a stable colloidal suspension of pigment particles. Their shelf life is 6 months, if stored in appropriate conditions (temperature between 20-25° C, low humidity and absence of dust), **Picture 2**. Pigment particles should also have the property of developing, at the required firing temperature, a wide colour range onto the base coat enamel.

Picture 2: Colorobbia Cinks packaging.

The ink is applied with specific ink jet printers. The machines are equipped with “bars” positioned transversally respect the direction of piece movement. Each bar apply a single color. Therefore the minimum number of bars onto a machine is four, even if, as anticipated, it’s possible to get till six or more bars depending on the project target of the machine, the image details definition and the desired colour range, **Picture 3**.

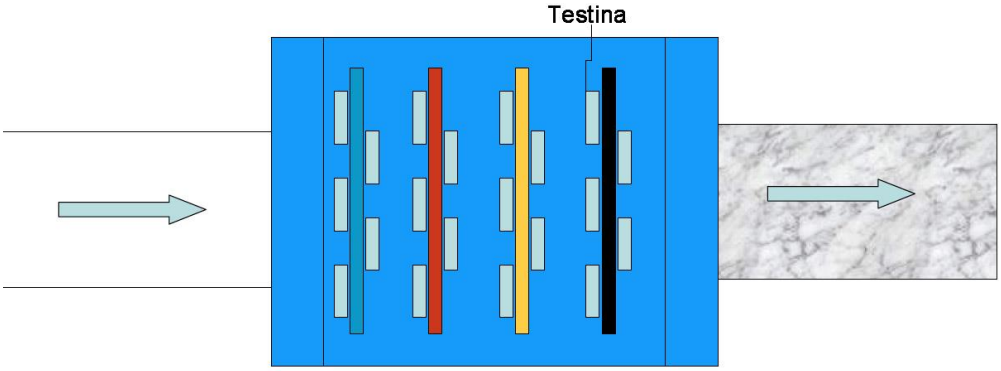
Picture 3: examples of running digital printing machines.



The bar is equipped with "printheads": the apparatus dedicated to the ink application. The printheads have a typical length in the range from 5 to 7 cm.

Each bar has to be equipped with the necessary printheads to cover the length of the piece to be printed, **Picture 4**. The printheads choice is a very important parameter to be taken into account during the design of the machine.

Picture 4: flow scheme of a four colour printing machine.



Printers are equipped with an adjustable speed pieces transfer device. A wet enamel should be applied on the pieces, then dried. The temperature of the piece in correspondence of the printheads should not exceed 40 - 45° C to avoid condensation of moisture on the heads or change of the ink viscosity due to the temperature. Both of these phenomena could adversely affect the proper application of the ink.

The printing heads are a very important part of the machine because their choice strongly influence the productivity and the reachable degree of complexity of the decoration.

The image quality in inkjet digital printing depends on:

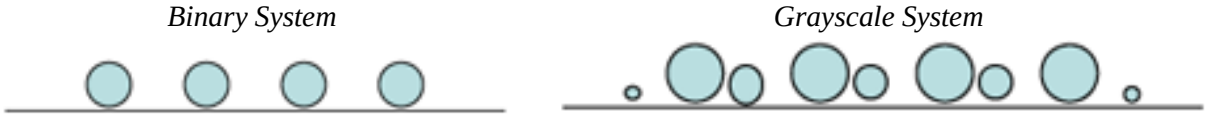
- Addressability and Resolution, are terms often used interchangeably to describe what is required to the printing system. The addressability describes, in general, the target of the printing system at design level, while the resolution is the result really obtained. They are normally measured as dpi (dots per inch).
- The ratio between addressability and capacity of the drops to spread on the piece.
- The prediction and therefore the management of possible drop positioning mistakes.
- The speed at which the printhead must apply the inks drops to achieve the required productivity.
- The combination printhead and ink: usually ink manufacturers are qualified by the printheads manufacturers.

In the market there are different types of printheads that can guarantee a certain resolution and productivity, in terms of the amount of ink per unit area.

The printheads could work with the following systems (**Picture 5**):

- Binary: all printhead nozzles spraying drops of the same size. Suitable for projects with a lot of ink discharge and with few details.
- Grayscale: the nozzles spraying drops of variable size, from 2 to 4 different sizes. Suitable for projects that use medium/low ink quantity with the presence of shadows and details.

Picture 5: Scheme of Binary and Grayscale system



The basic size of the ink drop is 12 pl (12 x 10^{-12} l), while larger drops could be obtained as multiples of the basic drop, up to a maximum of about 200 pl. The distance between the printhead and the piece in the ceramic field range from 2 to 5 mm, up to 10 mm in some cases where reliefs are present. This parameter is quite relevant in the definition of the resolution: the greater the distance the lower the resolution.

Digital printing applied to porcelain enamel

The exponential diffusion of digital technology in ceramic industry pushed the study of the application also in porcelain enamel world.

Taking into account that the support should be rough or porous, the investigation was directed on possible application of the technology on enamel applied by wet application and then dried.

At this point it was necessary to make a "profile" of the enamel per each:

- Kind of enamel used as base coating.
- Firing conditions.
- Choice of colours configuration.
- Available digital printer.

The profile allow to build up a data base that identifies the color development once fixed the up mentioned conditions and to predict deviations between the real color of an image and what is possible to obtain on the piece.

It was made a profile for each different porcelain enamel family:

- Ground coat and direct on enamels.
- Cover coat enamels: transparent, semi-opaque, white frits.

Concluding that only cover coat frits are suitable for the digital decoration and the color development improve when moving in the direction of white frits. The fusion flow and composition of the frits could affect the color development: on this point deeper investigation are needed.

The trials of transfer of an image on enamel gave promising results (**Picture 6**). The image show a good definition and an adequate colour development. Unfortunately lacking strong and brilliant colour, such as red, violet, orange, practically substituted by different brown nuances, and the intense yellow, substituted by a less brilliant yellow.

Picture 6: example of digital images transferred on porcelain enamel.

The application of the ink on the dry enamel cause a loose of gloss of the enamel surface after firing. The decor is, however, perfectly incorporated in the enamel and the resistance to abrasion and scratching is comparable to that of an enameled surface. To recover gloss it's possible to apply on decorated surface a transparent "glaze" with a thickness of about 30-40 microns. The choice of the glaze should be done with the target to guarantee the compatibility with the base coating, to avoid an influence on the quality of the enamel surface.

At the state of the art the application of this technology to the porcelain enamel must take into account the following constraints:

1. The surface of the piece to be decorated must be perfectly flat, even the piece deformation could drive to defects in reproducing the image. In theory it is technically possible to develop digital printers with movable printheads, capable of following any curvature of the surface to be printed.
2. The decoration should be applied on dry cover coat enamel, so that the parts have to be prepared with application techniques 2c/2f or 2c/1f or DWE
3. The images to be transferred should be selected taking into account that it is not possible to develop red, violet, orange and bright yellow colors. Their resolution and color range are linked to the type of printer, number of bars and type of printheads: in substance to the level of initial investment.
4. The surface of the decorated piece loose gloss, that could be recovered, if requested, applying a transparent glaze.

At the light of these constraints the possible practical application could be:

- Architectural panels, with particular attention to their design and construction in order to guarantee their flatness before the application of the decor.
- Signage and advertising panels.
- Pots and pans.
- Hobs and oven front controls, with flat shape.
- Other flat pieces.

Conclusions

Inspired by the recent development of digital printing in the ceramic world, some trials focused on the application of this technology to porcelain enamel have been realized.

The obtained results are very promising in terms of image resolution and color development, taking into account that have been used the same printers and inks of ceramic field.

In order to obtain an acceptable result the following constraints should be taken into account:

- The surface of the piece to be decorated must be perfectly flat.
- The decoration should be applied on dry cover coat enamel.

- It is not possible to develop red, violet, orange and bright yellow colours, especially in terms of intensity and brilliance.
- Decor surface with low gloss, that could be increased using a specific transparent glaze.

The possible application fields could be:

- Architectural panels.
- Signage and advertising panels.
- Pots and pans.
- Hobs and oven front controls, with flat shape.
- Other flat pieces.

Compared with decoration technologies currently in use, among which excels the screen printing, the digital printing could allow a significant improvement in terms of image definition, flexibility, productivity and cost, making it competitive for specific application fields.

References

[1] I quaderni di Acimac – ed. 2012 – "Colorobbia Digital Space: innovazione e sincronizzazione dei processi ceramici nello spazio Colorobbia" di Fabio Avoni

[2] I quaderni di Acimac – ed. 2012 – "La misurazione del colore in ceramica digitale" di Alessandro Beltrami

[3] I quaderni di Acimac – ed. 2012 – "La smalteria digitale" di Marco Ferrari

[4] I quaderni di Acimac – ed. 2011 – "Uno sguardo alla tecnologia inkjet per la decorazione di piastrelle ceramiche" di Terry O'Keffee, Baley Smith, Henrik Lauridsen