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Digital Printing Applied to Ceramic Decoration

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Abstract

Historically the decoration of ceramics has been performed by analog printing processes.

Collaboration between Ferro Enamel Espanola S.A and XaarJet UK has resulted in a capability to apply true ceramic inks to tiles in a fully digital operation.

The joint venture has required investment in the development of a full range of specialised colour inks, the refinement and optimisation of Xaar's piezo digital printing technology and their implementation in a rugged industrial machine.

In common with digital printing generally, this unique capability brings with it for the end user a number of key advantages –

- Low inventory
- Flexibility
- Minimal set-up time
- Every tile different
- Edge to edge printing possible
- Any size of image possible
- Process colour possible
- Profiled tile (full relief) printing possible

The synergy between Xaar's piezo ink jet technology and Ferro's unique ink formulations has resulted in an exciting route to growth in the otherwise broadly static market place for ceramic tile printing.

Introduction

Ceramic tiles coloured by glazed metal oxides is a technology that goes back over 5,000 years into history. Originally the oxides were applied using paintbrushes and more recently the use of screen printing has superseded this, at least in mass manufactured markets.

This paper describes how the bringing together of drop on demand printing technology and a specialised metal oxide ink formulation technology has resulted in a wholly unique and novel approach to this ancient process.

In order to succeed in this development, the project team had to overcome challenges in the fields of printhead technology, ink formulation, media formulation and media transport systems. This paper describes approaches taken to some of these challenges. It also looks at the commercial and technical origins of the product, the development of the product, the process of producing a digitally printed tile, and the benefits of using digitally printed images on tiles. Finally, it looks briefly at future developments in this area.

Origins of the Product

The major commercial driver behind the need to develop this product was that the company should attempt to find new market segments within which to operate, to increase revenue. As a result Ferro together with the machine integrator, Engineeria, formed a company, KERAjet, specifically to exploit the technology.

Of the major technical drivers that defined the development, probably the most important was a requirement to print onto profiled tiles. Profiles tiles are tiles that have a top surface which is not flat, for instance to simulate the surface of carved marble. Due to the limitations of screen printing technology, decoration of profiled tiles has always required a manual process. In order to achieve this, it is apparent that the optimum solution is a non-contact printing method.

An additional requirement was the wish to make every tile different, if required. This allows the more realistic simulation of natural product surfaces and produces a more pleasing aesthetic effect.

A number of alternative printing technologies were investigated in order to address these various needs. These included laser printing, litho printing, and continuous ink jet printing. None of these approaches gave fully satisfactory results.

Ferro first visited Xaar in December 1998 with a proposal for a development project to investigate the firing of a range of inks which they have previously developed, through a custom built printhead based on Xaar's piezo ink jet technology.

It was subsequently decided that a more cost-effective approach would be to base their development on a standard range of printheads, the 180 dpi, 500 nozzle XJ500 product.

Printhead, Ink, Media and System Challenges

The use of a drop on demand ink jet printer in a ceramics production environment presents a number of unusual challenges for the printhead. Environment in the manufacturing facility is hostile - dust and extreme temperatures are facts of life. In addition, inks formulated to print onto ceramics are completely different from inks required to print onto paper or other conventional office media. One difficulty which they present is that the 'as printed' colours are totally different from the colours which they present once fired into the final product. Another problem is that being rich in metal oxides, they tend to be electrically conducting, which can cause serious problems if they come into contact with the electronics controlling the printhead operation.

Colouration on ceramic surfaces is produced by the combination of metal oxides and glazes. The function of the ink in this technology is to apply the metal ions to the surface of the tile in the right densities and positions across the tile surface. In order to achieve this, the ink must carry high fractions of metal ions and must be jettable. These two properties tend to work against one another because they require the correct viscosity and surface tension to be maintained, which is difficult to achieve with high levels of solids in the formulation.

The finely ground glass or glaze that sits on the tile prior to firing has an important role to play in the final print quality. It must accept the ink and be resistant to smearing. It must also control the size of the dot of ink in the same way that ink jet papers are required to do. Finally, the glaze, in combination with the inks, must give bright, reproducible colours and a smooth, consistent surface finish.

The final part of the system, as with other printing systems is the media transportation. This is required to maintain the ceramic tile a constant distance from the printhead nozzles whilst moving the tile smoothly and accurately in a straight line at a constant velocity. To achieve this with a delicate ceramic tile up to 300mm square is in many ways a more difficult challenge than to do it with a paper substrate.

The Development Project

As noted above, the application requires a robust printhead. The XaarJet XJ500 is designed for use in rugged industrial applications such as label printing on packing lines. As a result, it required no further modification from a packaging standpoint to make it suitable. A more subtle requirement for the printhead relates to the interaction with the specialised inks developed. As a piezo driven technology, the XaarJet heads can, in principle, print most liquids, provided that their viscosities and surface tensions lie within certain specifications. However, the efficiency of energy coupling between the applied electrical impulse and the velocity of the ejected droplet is a function of these two parameters. As a result, a new ink has to be tested for its optimum firing voltage. Because ink changes its properties with temperature, optimum voltages are determined for a wide range of temperatures. A curve is then programmed into each printhead to allow the applied voltage to be varied with the measured temperature at the actuator. As a result of this flexibility of the printhead, it was easy to adapt the firing properties as the ink properties were evolved and refined. An example of firing voltage vs. temperature curves are shown in the figures below:

The printhead also needed to be protected internally due to the electronically conductive nature of the inks. The solution to this was found to be the use of Parylene coating of the electronic circuitry of the printhead. Parylene is a polymer material that coats conformally on to surfaces from a vapor. As a result, it was possible to achieve this modification by the addition of a hole in the housing of the head through which the Parylene passed and coated the surfaces. This was then sealed by the addition of a small capping component.

The original ink that Ferro had developed was based on a highly volatile solvent. This proved to be difficult to fire due to the tendency to clog in the nozzles too quickly.

A joint development between Xaar's and Ferro's ink teams resulted in alternative approach based on Ferro's Metal Oxide formulation in solution in a high molecular weight organic solvent.

This resulted in printing behavior comparable to the oil-based ink printing that has become well established at Xaar and its customers.

The ink derives its colour properties from metal oxides, which combine with the glaze during firing in a process that ceramics technologists have refined over centuries. In order to produce an ink which fires smoothly and contains no nozzle-blocking particles, the ink team opted for the use of metal complexes as the carriers for the metal ions. This had the benefit that the complexes dissolved ink a solution in the solvent, rather than being a dispersion of particles. As such it resembled a oil based dye ink and fired extremely reliably through the printhead. Good colour quality has been achieved by the skillful combination of metal complexes in the correct ratios.

The substrate on to which the ink is applied is a pre-fired (biscuit fired) ceramic tile covered with a thin layer of powdered glass or glaze. The glaze is applied as a wet slurry which is dried before the printing process. Careful formulation of the glaze has resulted in a surface, which behaves very much like the surface of coated paper. The characteristics of the wetting behavior are controlled by the chemistry of the ink, its surface tension and also the size of the glaze particles.

Through the careful development and control of the glaze dispersion, very repeatable results are routinely achieved.

The transport system is based on a conveyor built approach. The belt takes the tile and moves it at a constant velocity under the printhead, which fires at a constant number of drops per second. The tile is detected by an opto-sensor placed a fixed distance from the printhead. The sensor detects the moment when the leading edge of the tile

crosses its path and starts the printhead printing after a suitable delay.

By paying attention to the ambient level of vibration, and the material of the conveyor belt, the mass of the tile is sufficient to maintain control of position and achieve the required print quality.

Dust is excluded by the use of carefully designed covers. The nozzle plate is cleaned by the use of a specially developed maintenance station, which moves into place while the printheads are retracted from their normal positions.

The Process of Producing a Digitally Printed Tile

Digital printing of ink on to tiles results in an overall process flow as follows –

- Mould clay tile
- Biscuit fire
- Glaze applied as wet slurry
- Glaze dried
- Inks printed from Xaar DoD piezo printhead
- Tiles fired

The Benefits of the Technology

There are many benefits of taking the approach described –

- Profiled tile (full relief) printing is possible, thus allowing the automation of high value tile production which up to now would only be done manually
- Every tile can be different, giving more natural and aesthetic effects
- No set-up is required unlike the screen printing technology it replaces
- Any size of image is possible allowing any shape or size of tile to be processed
- Edge to edge printing is possible, meaning that tiles can be printed with no interruption of pattern across the boundary
- Flexibility of use, because different styles of tile can be handled in sequence, or even together
- The unit is a stand-alone device which can readily substitute for a existing screen-print machine
- All image data is resident on driver cards within the machine and images can be readily downloaded by connection to a computer at any time
- Process colour is possible in contrast to the limitations imposed by screen printing technology
- A small machine footprint compared to the screen print equivalent
- The machine has proved to require only low levels of maintenance to achieve reliable running
- No wastage – all the ink used is printed on to the tiles resulting in elimination of the large volumes of effluent produced by traditional techniques
- Lower manning levels, aiming towards unattended running of the production lines. The compares favorably with a typical workforce of eight to man the equivalent screen print line.

Future Developments

Although the technology has yielded great benefits for the user already, both Xaar and Ferro are looking to improve the performance still further by moving to new ink formulations giving brighter colours coupled with a lower cost per tile.

Conclusion

This joint development has shown that a robust, flexible drop on demand ink jet technology combined with specialist market knowledge and ink formulation skills can lead to a revolution in an otherwise static, established market. There are almost certainly other such opportunities waiting to be discovered and exploited by the imaginative use of digital printing techniques.

Biography

Mr. R. A. Harvey is a mechanical engineer with a track record of work in micro-engineering and systems design. He has developed a wide range of products in industrial and scientific instrumentation, and had been involved in the development of Xaar technology for over ten years. He is currently Engineering Manager at Xaar Technology Limited.