A Guide to Ceramic Tile Digital Decoration

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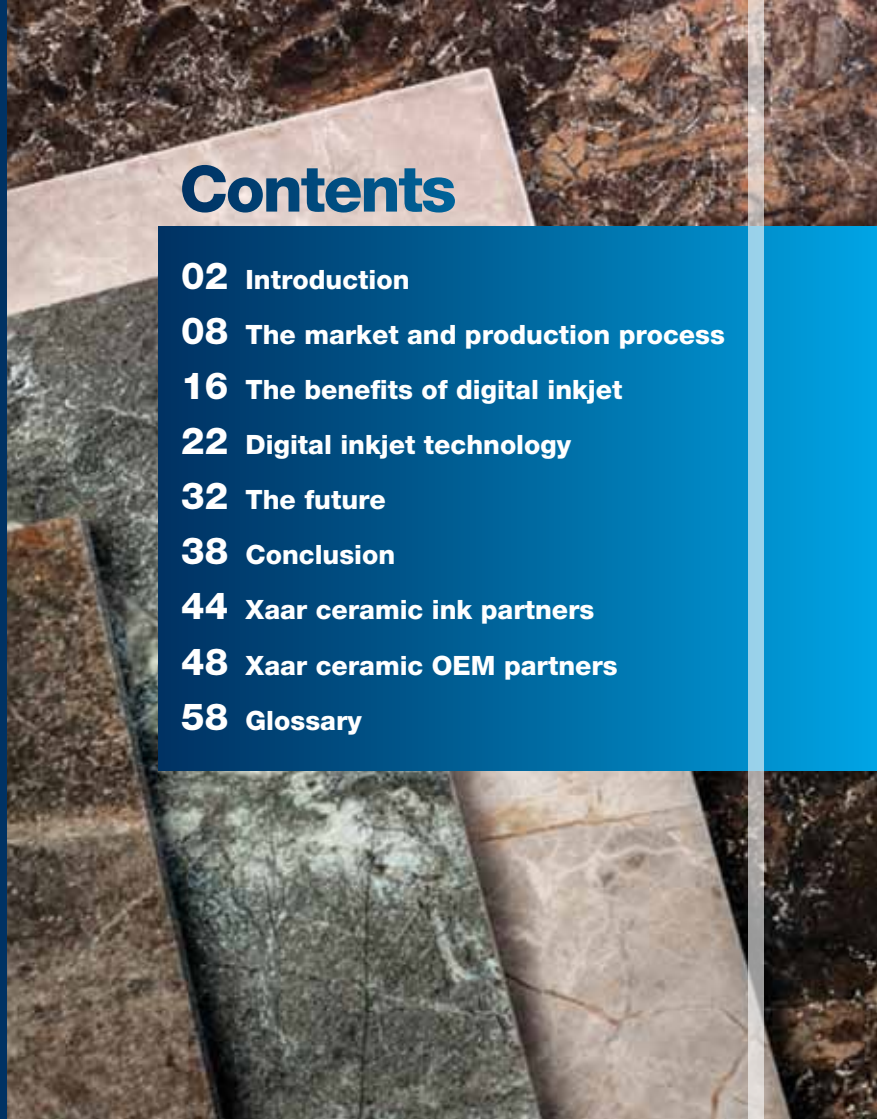

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Digital inkjet printing has revolutionised ceramic tile manufacturing in a very short time – and the revolution has been so sweeping that it's sometimes difficult to remember what the ceramics industry was like until relatively recently.

Just over a decade ago, the only way to decorate ceramic tiles was using traditional printing methods, the most common of which was screen printing, and the industry as a whole had little use even for computers. Screen printing was a mature technology with little scope for innovation.

Most of the tiles produced were either plain or unsophisticated with simple and repetitive patterns. It was difficult for manufacturers to make their tiles stand out from the competition and differentiation was mostly down to price. The decoration process had other disadvantages, including high set-up costs, long production runs, and the difficulty of exactly matching tile colours on repeat orders.

Today, digital inkjet is the 'must have' technology for ceramic tile manufacturers. It is no longer a case of offering digital tiles as an 'optional extra'; digital capability is expected, and digital inkjet is the only viable option.

Digital inkjet printing has revolutionised ceramic tile manufacturing in a very short time

The revolution began in Europe, where digital ceramic tile decoration flourished in the difficult economic conditions from 2008 onwards. The European market saw a significant reduction in the building of new properties – the primary source of demand for new ceramic tiles. Tile manufacturers who embraced digital decoration found that their life-like designs, at cost-effective prices, captured an increasing share of the shrinking demand. It was no exaggeration to say that 'going digital' was the difference between success and survival. The combination of benefits such as life-like designs and improved tile quality with reduced costs gave digitally-equipped ceramic tile manufacturers a huge advantage over rivals who were still using traditional methods.

Today majority high proportion of ceramic tile manufacturers in the major European producing countries, Spain and Italy, have already converted to digital inkjet printing. These manufacturers have all cut production costs, reduced waste, work-in-progress and stocks of finished products, and improved responsiveness to design changes and customer demand.

They are also producing higher-quality tiles that offer more realistic reproduction of marble and other natural materials. And they are doing so in the short runs that buyers demand – using digital, a single ceramic tile can be produced cost-effectively. Instead of competing on price, these manufacturers can compete on creativity and innovation, and do so in new markets.

As the global economy recovers, these companies are well-placed to reap the rewards of their forward-looking investment.

We are now seeing the change from traditional to digital ceramic tile decoration gathering momentum in the rest of the world. China, Brazil and India, countries with an enormous installed base of traditional ceramic tile production lines, have already shown a very rapid conversion to digital inkjet decoration. As worldwide production of ceramic tiles grows – in 2012 it reached 11 billion m^2 – it has created huge opportunities for suppliers of digital inkjet ceramic tile printers and ceramic inks.

This Xaar guide explains why and how this revolution has come about. You may be a ceramic tile manufacturer interested in the significant production benefits and efficiencies of digital inkjet decoration, or wanting to broaden and deepen your product range with innovative new designs. If you are, the guide will explain how exactly digital inkjet decoration can transform your business and – very importantly – help you arrive at the right printhead technology to enable you to achieve your goals.

Or you may be an Original Equipment Manufacturer (OEM) developing a digital inkjet printer. This guide will give you the information you need to choose the best partner to supply, integrate and support the all-important printhead.

Or you may simply be curious about the history of the take-up of digital inkjet printing technology in ceramic tile decoration. How has a technology from label printing and wide-format graphics printing managed to transform a vastly different market segment in such a relatively short time?

Introduction

Whatever your reason for wanting to know more about the digital decoration of ceramic tiles, we hope you find this guide useful. We begin by describing traditional ceramic tile manufacturing and establishing the place of printing in the process. Next, we look in detail at the benefits that digital inkjet brings and the reasons why it has had such a dramatic impact on the industry.

The most important section of the guide explains the crucial role of the inkjet printhead, and complementary functions, in delivering high-quality print in the reliable, consistent manner demanded by ceramic tile manufacturers, under the harsh manufacturing conditions in the ceramics plant. We pay particular attention to the revolutionary TF Technology™ and Hybrid Side Shooter™ architecture in Xaar's range of printheads, and how they address the need for true ink recirculation to enable maximum production uptime. The Xaar 1001 family, launched in 2007, is recognised as the 'breakthrough technology' that drove the digital transformation of the ceramic tile manufacturing market. The all-new Xaar 1002 family, launched in 2014, delivers enhanced print quality and printhead robustness establishing a new standard in single-pass inkjet printing.

Finally, we explain what the latest printhead developments will bring to the creative mix, and outline Xaar's vision that the entire manufacturing process will become digital in the future.

The market and production process

As noted earlier, in 2012 the global production of ceramic titles was 11 billion m² – a rise of 6.2% over 2011. China continues to be the biggest manufacturer – responsible for 46.5% of the world's ceramic the production.

The sheer scale of ceramic tile production facilities that produce those 11 billion m² is very impressive. They occupy significant areas of land, situated close to the raw materials they consume. They also house a capital-intensive process that uses enormous amounts of water, hydraulic pressure and heat, among other resources. These large manufacturing facilities require large-scale equipment – hydraulic presses, ceramic tile kilns, and so on. Traditional manufacturing sites also need large areas in which to store work-in-progress and finished tiles.

How tiles are made

The first step in manufacturing ceramic tiles is to quarry and refine the various sands, clays and other raw materials used. These are then transported to the ceramic tile plant, where they are stored until required.

In 2012 the global production of ceramic titles was 11 billion m² – a rise of 6.2% over 2011

The materials are dry and in powder form when they arrive, and must be milled into finer powders before they are mixed in the right proportions and fed into tanks where water is added. The liquid material this creates is called 'slurry'. The next stage is to return the slurry to a powder form, which is done by spraying it into a large tank and feeding in a current of hot air. As the slurry becomes airborne it rapidly dries to form a fine, atomised powder.

The powder is then ready to be moulded into a ceramic tile body. Large hydraulic presses are used to compact the powder under extremely high pressure – up to 400 kg/cm^2 – which generates a lot of heat. The combination of the heat and pressure from the press forms the unbaked tile, or 'biscuit. The press also gives the ceramic tile its size, shape and, in the case of digitally-decorated ceramic tiles, its texture. The tile may then be dried further to remove more moisture and ensure it remains stable on its way to the kiln.

The residual moisture in the powder gives the 'biscuit' some strength, but as the name suggests, it is still very fragile. After applying the glaze (liquid coating containing glass or 'frits') the tile is now ready to be decorated. As we explained in the Introduction, screen printing (flat or roller) has traditionally been used, applying each of the colours in the pattern using a separate roller. (We will look more closely at what the printing process involves in a moment). As well as enhancing the aesthetic appeal of the tile, glazing and printing add features such as water repellency, durability and hygienic properties to the product.

The final stage in production is to fire the tile in a kiln. This process solidifies the body of the tile and fuses the frits in the glaze and the decorative inks to generate the final pattern on the tile. The kiln is usually the most expensive piece of equipment in the manufacturing plant and it is therefore optimal to keep the kiln running 24 hours a day, 7 days a week, avoiding wasting energy each time it has to be ramped up to the correct temperature. As a result, there will often be more than one ceramic tile production line feeding each kiln with tiles ready for firing.

Kilns come in different designs, but a roller hearth kiln – the most efficient – can be several hundred metres long. As the tiles pass through the kiln – which can take over an hour – the temperature gradually increases until at the centre of the kiln it reaches around 1200˚C. After this, the tiles cool down before they leave the kiln. They are then sorted into batches and large stacks of identical finished tiles are stored ready for distribution.

The limitations of the traditional process

The traditional production process has several disadvantages. For one thing, the kiln is most efficient when handling large batches of tiles – yet consumers and retailers increasingly demand short runs and 'Just in Time' deliveries. The most serious weakness, however, is in the decorating process, because roller screen printing is a contact printing technology. This has a negative impact on ceramic tile manufacturing in a number of important ways.

For example:

- **Long set-up times:** The biggest disadvantage of conventional decoration is the amount of time needed to set up the printing jobs. Traditionally, each design change needs new silk screens, or roller sleeves, plus the time and effort needed to check colour consistency. It can take as much as 30 minutes to change the rollers and wash down the printer.
- **Colour management is difficult:** Ensuring consistent, repeatable colour is important in all print applications, but especially so in ceramic tile decoration. The problem is that the colour of the tile when it leaves the decoration printer is different from the colour after firing. The extremely high temperatures in the kiln fuse the frits in the glaze with the pigments in the inks and reveal the true colours of the tile. Each roller change has to be followed by at least one test firing of the printed tile to check colour, which can bring the total changeover time to two hours, and cause more waste and extra costs.
- **Inflexible production planning:** The inflexibility we have described makes production planning very difficult. For example, the combination of long set-up times and tricky colour management works against those short runs and 'Just In Time' supply chains that the market demands. Also, consider what happens in the decorating department at the end of a typical two-shift working day, when the manager receives the patterns for the next day.

First, the operator changes the roller sleeves. Next, he prints some sample tiles and takes them to the kiln for firing. This takes approximately 2 hours; if the colour is right, his job is done. If it isn't, he has to start the process all over again, and all the time materials are being wasted and costs incurred.

- **Patterns repeat frequently:** The circumference of the roller determines the length of the image it can print, and therefore how frequently the pattern repeats. This limits design options – and hence creativity – and makes tiles less life-like. Before the arrival of digital inkjet printing very high levels of skill were required to produce the most attractive and highest-quality tiles. The Italians and Spanish were recognised as specialists who could create fantastic designs – but at high cost.
- **Only flat tiles can be decorated:** A contact technology cannot print on textured, 3D tiles, only on flat tiles. In addition, screen printing cannot print right up to the edge of the tile, so tiles have a white, unprinted border.
- **Tile breakage is more common:** Printing takes place while the tile is still fragile, and the pressure of the roller on the 'biscuit' can easily fracture it. Each time a tile is broken, not only is the biscuit wasted, but also the glaze and the inks. Combine this with the reduced output and it is clear that there are significant cost penalties.

- **High stocks of finished goods and work-in-progress:** The need to operate the kiln 24/7 and the difficulty of matching colours encourage long runs and the holding of substantial stocks of finished goods. If a repeat order comes in, it is easier to meet it from existing stocks than to try to reproduce exactly the same colours and risk the problems caused by poor batch control or a slight change in the ink or glaze. (We are all familiar with checking batch numbers when we buy ceramic tiles.) The same is true of work-in-progress, large batches of which are often stacked around the factory awaiting test firings to verify the colour consistency. Furthermore, space must also be found to store the screen drums needed to produce repeat print runs.

The digital solution

Clearly the ceramic tile manufacturing industry needed a decorating solution that overcame the very considerable challenges described above. What's needed is a printing technology that, among other things, doesn't break tiles, has minimal job changeover and set-up times, offers effective colour management, and can produce short runs. If it can also apply much more life-like patterns, including textures, to expand creative design opportunities, even better. Finally, we want it to do all these things reliably, shift after shift, be straightforward to integrate into the existing production line, and pay for itself in just six months.

In the next chapter we look at how digital inkjet delivers all these benefits, and more.

The benefits of digital inkjet

Digital printing, using various technologies, has been around for some time. The first digital colour press for commercial printing – developed by Indigo – appeared in 1993, and since then digital techniques have had an impact on every sector of the printing industry. Digital printing has reduced costs, streamlined production processes, and made possible new products and business models.

Digital printing's history in ceramic tile manufacture is shorter, however. The first digital printer to use inkjet technology to decorate tiles was launched in 1999 by KERAjet, with very limited success, and it wasn't until 2007 that digital tile decoration really broke through and became the 'must have' process it is today. The catalyst was the launch of the Xaar 1001 printhead and its integrated ink recirculation technology (TF Technology™). We will explain why in the next chapter, where we look in-depth at how the design of inkjet printheads has evolved, overcoming the issues that originally held the technology back.

First, let us look at how the features of digital inkjet decoration solve some of the problems with traditional rotary screen printing.

The catalyst for change was the launch of the Xaar 1001 printhead

Non-contact

For ceramic tile decoration, the first major advantage of digital inkjet is that it is a non-contact process. The distance between the substrate (the ceramic tile) and the printhead is generally 3-5 mm. This means that, unlike in the rotary screen process, no mechanical pressure is put on the ceramic tile, which is fragile. As a result, breakages are minimised.

Non-contact also means that digital inkjet printers can print on uneven surfaces to decorate textured tiles. The texture is added to the ceramic tile biscuit during the pressing process, and the printhead is then able to jet ink into the recesses that rotary screen printing cannot reach. As we will explain later, Xaar is aiming to extend the digitalisation of the manufacturing process with a new prinhead capable of applying texture to the tile, delivering even more creative benefits.

Digital inkjet printers can also decorate right to the edge of the tiles, eliminating white edges and creating seamless expanses of tile.

Creative benefits

Digital inkjet printing has a number of creative benefits. There is no roller, so there is no forced limit to the pattern size – the size of the pattern is only limited by the size of the memory in the printer electronic sub-system.

Xaar's latest generation of printhead electronics, for example, can store enough data to reproduce a pattern of 40 m² with no pattern repeats. A whole room can be laid with individually patterned tiles.

Inkjet printing can also apply designs of the highest quality and in the finest detail, creating extremely life-like ceramic tiles that are very difficult to distinguish from real marble and stone. The 360 dpi resolution and greyscale technology used in the Xaar 1001, and the new Xaar 1002 printheads can reproduce an effective resolution of more than 1000 dpi, which is as much as a good human eye can distinguish.

Faster set-up

We saw in the last chapter how much time it takes to set up a traditional printing line. On a digital inkjet printing line the set-up is handled by the print control software, so there is no need to physically change the rotary drums to print a new pattern. It is therefore easy to print short runs. The operator can even interrupt a production run to test-print a number of different patterns in preparation for the next day's production; there is no need to wait until the end of the shift. The minimum print run with digital inkjet printing is just one tile – ideal for producing test tiles and perfect for the short print runs required today.

Colour management, too, is software-controlled and is a more sophisticated and predictable process than on a traditional printing line. This has led to reductions in the number of glazes and ink sets used, further improving the efficiency and reducing the costs of ceramic tile manufacturing.

Taken together, these factors make it easier to replicate patterns and colours, and they also have a significant positive impact on the stocks of work-in-progress and finished products that have to be held. Being able to fulfil a repeat order, for example, only depends on having the pattern stored digitally and the ink vendors supplying the same ink.

Lower ink costs

It is important to understand that none of the above advantages could have been realised without one other vital element – the 'open' ink model historically used in the ceramic tile market. Ceramic tile manufacturers are free to buy their inks from the most competitive source and are not obliged to buy from the printer manufacturer; they are thus free to change inks as often as is commercially attractive. The open ink model has provided sufficient competitive pressure to reduce the price of digital inks in the ceramic market, and has been a significant contributor to the adoption of digital printing in ceramic tile production.

Rapid payback – in less than six months

Thanks to all the above benefits, a digital inkjet ceramic tile printer can pay for itself in less than six months.

To recap, this is because costs are lower, due to reduced tile breakages, less ink consumption, and the lower ink prices from the open ink model. Faster, simpler set-up enables the short production runs that the market demands, and makes the production line much more flexible.

Reliable software-driven colour management reduces stocks of finished tiles and work-in-progress, freeing up capital. Digital storage enables patterns of almost infinite size.

Profit margins are higher, because the final products are of higher quality, closely resemble real marble and stone, and exhibit greater creativity than traditionally-printed tiles.

These are all good reasons for adopting digital inkjet printing. There are, however, different implementations of digital inkjet printers on the market, and several important factors must be taken into account in choosing between them. We look at these next.

Digital inkjet technology

As we have seen, today digital inkjet decoration has been widely adopted in Europe, where it has become the essential technology for ceramic tile manufacturers, and is now also growing fast on other continents, but its success did not come overnight. Almost a decade passed between the launch of the first digital inkjet printer targeted at the ceramics sector, in 1999, and the real start of the digital revolution in the industry in 2007. This is because it took time to develop printhead technology capable of printing tiles consistently, to the right quality, and reliably.

To understand why, we need to briefly explain how a printhead works. An inkjet printhead jets drops of ink onto the substrate (in this case, the ceramic tile) to create the image. There are two basic ways of doing this – continuous inkjet or Drop-on-Demand (DoD) inkjet. Digital ceramics decoration printers use DoD.

DoD printing means that a drop of ink is only generated when it is needed, so ink waste is minimised. To do this, the ceramic decoration printers use piezoelectric inkjet printheads. The active components in these printheads are made from a ceramic material (PZT) that flexes when a voltage is applied to it. The Xaar 1002 printhead family employs PZT material in a unique Hybrid Side Shooter™ architecture, which we will explain in more detail later.

Piezoelectric printheads can work in two ways: direct (bend) mode or shear mode. In direct mode, the electrical field (voltage) is applied to the PZT material in the same direction as it is polarised, which causes it to change in height and width (it becomes longer and thinner).

Today digital inkjet decoration has been widely adopted

It is this expansion that is used to push or bend a membrane and force a drop of ink out from the nozzle in what are called 'end-shooter' printhead architectures.

Xaar printheads work in shear mode. The Xaar 1002 uses Xaar's patented Hybrid Side Shooter™ architecture, in which the electrical field is applied perpendicular to the polarisation of the material. This causes the piezoelectric crystal to shear, rather than lengthen or shrink. Using two pieces of ceramic material for the wall of the ink chambers, and then applying the voltage, causes the composite material to flex in the middle: the effect resembles a chevron. The chevron flexing is done at a very high frequency which creates an acoustic pressure wave that travels through the ink chamber. It is this pressure wave that forces the ink out through the nozzle in a droplet. This chevron structure is very energy-efficient, reducing the driving voltage required and so reducing power consumption and heat generation. For example, the Xaar 1002 uses less than 1/3 the voltage required by direct mode DoD digital inkjet printheads.

Two chevrons are used to create the walls of each firing chamber. The top of the chamber is also PZT, and the bottom is formed with Xaar's patented nozzle plate. The nozzle is, therefore, perpendicular to the flow of ink through the firing chamber and hence we have Xaar's unique Hybrid Side Shooter™ architecture (HSS™).

All this takes place on a micro scale. Inside a typical printhead, the ink channels are only a few tens of microns across and the nozzles are typically 20-50 microns (µm).

A 1 picolitre (pL) ink droplet is typically 13 µm in diameter. Compare this with the width of a human hair, which is approximately 80 µm.

The ceramic decoration environment is challenging

Ceramic decoration presents several challenges. Firstly, the manufacturing process generates a lot of dust and debris, because the raw materials are powders. Secondly, after leaving the press the unfired ceramic tiles are fragile, hot and steaming. Finally, to produce vibrant colour, ceramic inks contain large, insoluble particles of pigment, packed tightly together and held in suspension. This makes the ink very viscous and liable to settle, causing sedimentation.

The first digital inkjet tile printers, which appeared around 2000, could not cope with these challenges. The early printheads suffered from poor reliability: blocked or deviant nozzles caused unwanted white and dark lines on the tiles, and needed frequent maintenance to clear the nozzles of ink and other debris. The excessive downtime this caused made the printers totally unsuitable for single-pass industrial-scale decoration, which demands that all nozzles must work to their full potential all the time.

There were other problems as well: the print quality was poor, with grainy images due to the low resolution of the binary printheads; replacement parts were expensive; and inks had a limited colour range and were expensive.

The major reason for the problems with early piezoelectric printheads was their design: most were direct mode based on the 'end shooter' architecture described earlier. In an end shooter printhead the firing chamber has one ink inlet and one outlet (the firing nozzle), and the ink flow is from inlet to outlet. The potential 'achilles heel' with all end shooter designs is that nozzles can fail, either because they are blocked by particles in the firing chamber, caused by agglomeration of the ink or the ink settling in the chamber, or by air bubbles forming, which also blocks the nozzles. Such a failure then requires a 'purge/wipe' maintenance routine before printing can resume, leading to more downtime.

These issues with end shooter printheads held back the adoption of digital decoration until 2007, when Xaar launched the Xaar 1001 GS6 printhead. The Xaar 1001 GS6's 6-pL drop size enabled it to reproduce fine detail, smooth tones and life-like images, but what transformed the market's perception and experience of digital decoration were Xaar's unique Hybrid Side Shooter™ (HSS™) architecture and patented TF Technology™ ink recirculation, complementary technologies that work together to deliver unrivalled reliability and maximum production uptime.

As described earlier, as well as an inlet and an outlet for ink flow, HSS™ has a separate nozzle in the side of the ink channel – not at the end – through which the drop of ink is fired perpendicular to the flow of the ink. Added to this, the unrivalled TF Technology™ – the only true ink recirculation system – ensures the highest ink flow across the back of the nozzle during drop ejection, which carries any particles or trapped air bubbles away in the ink path, not forcing them into the nozzle. This means nozzles are continuously primed and kept blockage-free, ensuring that the printhead is fully operational for the maximum length of time. The Xaar 1001 printheads were self-priming, so start up and self-recovery is fast after, for example, a mechanical shock. Only one tile would be lost and there would be no need to stop the whole production line.

In 2012 Xaar expanded the range with the Xaar 1001 GS12, a larger-drop version (12 pL smallest drop) of the original Xaar 1001 GS6. The larger drop increased the amount of colour that could be achieved and made the Xaar 1001 GS12 perfect for floor tiles, where deep, rich browns or dark stone colours are preferred. Alternatively the Xaar 1001 GS12 could be used to increase the speed of printing whilst still achieving the same level of colour as the Xaar 1001 GS6.

More recently, in 2014, Xaar released theXaar 1002 family of printheads incorporating multiple innovative technology features, drawing on Xaar's many years in the ceramics industry to improve drop volume uniformity and drop placement accuracy for an even higher quality printed image. Available, like the Xaar 1001, in GS6 and GS12 versions, the Xaar 1002 printheads feature 1000 Optimised Geometry nozzles that can jet and place drops with the highest precision on the market. As a result the new printheads produce the smooth tones and solid areas needed to replicate natural materials that are stunning replications of the real thing.

Ink recirculation is vital

The importance of TF Technology™ ink recirculation cannot be stressed too much. Ink recirculation keeps the ink in constant motion, preventing sedimentation and nozzle blocking. This is essential when printing heavily-pigmented, highly-viscous ceramic decoration inks and the Xaar 1002 can jet inks with a much wider viscosity range than other printheads can.

With the TF Technology™ solution to ink recirculation, high volumes of ink are circulated past the back of the nozzle during printing – the ink flow rate is much higher than that achieved by any other printhead. This method is unique to the Xaar 1002 (and to the Xaar 1001 it replaced).

Other manufacturers offer what they call 'recirculation' but they use different methods. For example, in many end shooter printheads ink circulates in an upper chamber of the printhead but not in the lower chamber, which means there is no recirculation past the back of the nozzles in the lower chamber. The piezoelectric material sits on the roof of the lower chamber and presses downwards to push the ink down and out of the nozzles. This creates a vacuum and ink can be sucked into the lower chamber from the upper chamber. Any debris or air bubbles that enter, or accumulate in the lower chamber, can still only be removed by pushing them out through the nozzles, which can cause the nozzle to block.

As a result, printheads without TF Technology™ are less reliable, leading to longer and more frequent maintenance cycles, increased downtime and consequently a higher cost of ownership.

Outstanding print quality

The Xaar 1001 and1002 printheads have driven major advances in digital inkjet decoration in other ways, particularly in delivering outstanding print quality using XaarDOT™ greyscale technology. XaarDOT™ allows variable-sized drops of ink to be placed on the tile. There are several advantages in variable drop size. The high native nozzles per inch (360 npi) of the Xaar printheads enables pin-sharp patterns to be achieved using the smaller drop sizes; and drop size selection allows printing on tile types of different absorbency and into different glazes, enabling a much wider gamut of colour to be added to the tile.

To print variable drop sizes – described as 'greyscale printing' – small droplets are fired very rapidly, one after the other. These 'sub-drops' coalesce as they leave the nozzles. In the Xaar 1002 GS6, each sub drop is 6 pL, which creates seven final drop sizes from 6 to 42 pL. Drop sizes can be chosen dynamically. In fact, combining the high native resolution with greyscale means that the Xaar 1002 printheads have an effective resolution of over 1000 dpi, which is at the limit of what the human eye can perceive. In other words, the image appears perfect at normal viewing distances. This results in amazingly life-like images and with the Xaar 1002 GS6.

The Xaar 1002 GS12 printhead jets larger 12 to 84 pL drops, delivering even more ink for bolder tile colours and effects. Alternatively, the Xaar 1002 GS12 can deliver the same ink coverage as the Xaar 1002 GS6, but at double the print speed. With both printheads the improvement in the quality of print is significant compared to what can

be achieved with binary printheads, where the drop size is always the same. This enables ceramic tile manufacturers to achieve a stunning replication of natural materials like marble and granite, as well as highly decorative creative new designs.

Watch Xaar technology come to life

You can explore further inside the Xaar 1002 printheads by downloading Xaar's 'Xapp' app from the Apple App Store onto your iPhone. Use the Xapp AR feature to scan the Xaar AR trigger images and view 3D animations showing how the Xaar 1002 works. The animations show, for example, the patented TF Technology™ combined with HSS™ architecture in action. Ink is shown flowing directly past the back of the nozzles, ensuring they are continuously primed and remain blockage free.

Ink optimisation

To achieve the high quality and special effects that consumers expect on ceramic tiles, ceramic ink manufacturers have created innovative new inks specifically for digital inkjet printing. Xaar fine-tunes the way the printhead fires the drop for each of our approved inks to ensure reliable, accurate jetting. This is called 'waveform optimisation'. Under the open ink model described earlier, Xaar works directly with its ink partners to develop a waveform for each ink/printhead combination.

This ensures drop placement accuracy, optimised operating voltage, print reliability and, ultimately, increased throughput. The Xapp app can also be used to explore the benefits of using optimised waveforms. Once successfully validated and approved, the digital ceramic ink is warranted against long-term damage to the printhead and the optimised waveform will deliver unrivalled print performance and trouble-free operation. (Go to **www.xaar.com** to see the range of ceramic inks approved for use with Xaar's ceramics printheads).

Drive electronics

So far we have spoken about the mechanical operation of the printhead itself. However, it is important to understand too how the printhead is instructed to print a specific ceramic tile design. After first being created in the design studio, each design is transferred as a bitmap image format to a PC, where it is usually manipulated to generate separate colour versions of the same design.

A digital decoration printer is generally controlled by a further PC. This first receives the image file before passing the data to the Xaar drive electronics which decode the image and pass the appropriate signals through the HPC (Head Personality Card) to the Xaar 1002 printheads. The Xaar drive electronics are easy to configure and straightforward to integrate, simplifying printer construction for manufacturers.

The future

Around the world, the conversion of production lines to digital inkjet decoration continues. Just as this 'first wave' of digitalisation sweeps through, a second wave is arriving, one that provides ceramic tile manufacturers with even more ways in which they can differentiate their products from their competitors'.

Xaar's vision is for the digitalisation of the whole ceramics manufacturing process, with multiple digital inkjet printers sharing a common 'command and control' centre. The first process step, described earlier, is tile pressing. Part of this process generates the texture or structure on the tile and Xaar sees this being added digitally in the future.

This is a major advance. The non-digital technique – applying texture at the pressing stage – is an expensive process, and replacing it with digital technology further reduces set-up costs and time. It also makes it possible to change the relief image on every tile, in the same way that the decorative pattern can be changed, and designers are able to synchronise the texture and coloured patterns for even more realistic final tiles.

The conversion of production lines to digital inkjet decoration continues

Digital deposition also benefits another emerging area of ceramic tile manufacture – large, thin tiles, which are manufactured by extruding the base material rather than by pressing it. Such thin tiles are naturally less robust, and the additive, non-contact digital process can be used to add texture while avoiding breakage. It also increases the attractiveness and natural look of the tiles.

As with the first wave of digitalisation, innovative new printhead technologies are driving these developments, because digital printers that add structure and relief need to be significantly different from the digital decoration printers used today. On average, the latter lay down 2-8 g/m^2 of coloured ink, but to add relief to a tile requires hundreds of grammes per square metre. In addition, the particle size needs to be significantly larger than that used today.

Once again, Xaar is leading the way in developing the printheads capable of applying structure. The new Xaar 001 printhead can jet drops in the nanolitre size range rather than the picolitre range, featuring a drop size of between 70 and 180 nL – a factor that is 1000 times greater than the drop size of present DoD printheads. This enables the printhead to jet digital glazes and other fluids with very large particle sizes, and lay down more than 200 g/m^2 on a tile.

Printers capable of this level of fluid laydown could also be used in other applications, such as applying the engobe and glaze to the tile body. Using digital technology in these applications could reduce the amount of fluid used and allow further creativity to mix effects on a tile.

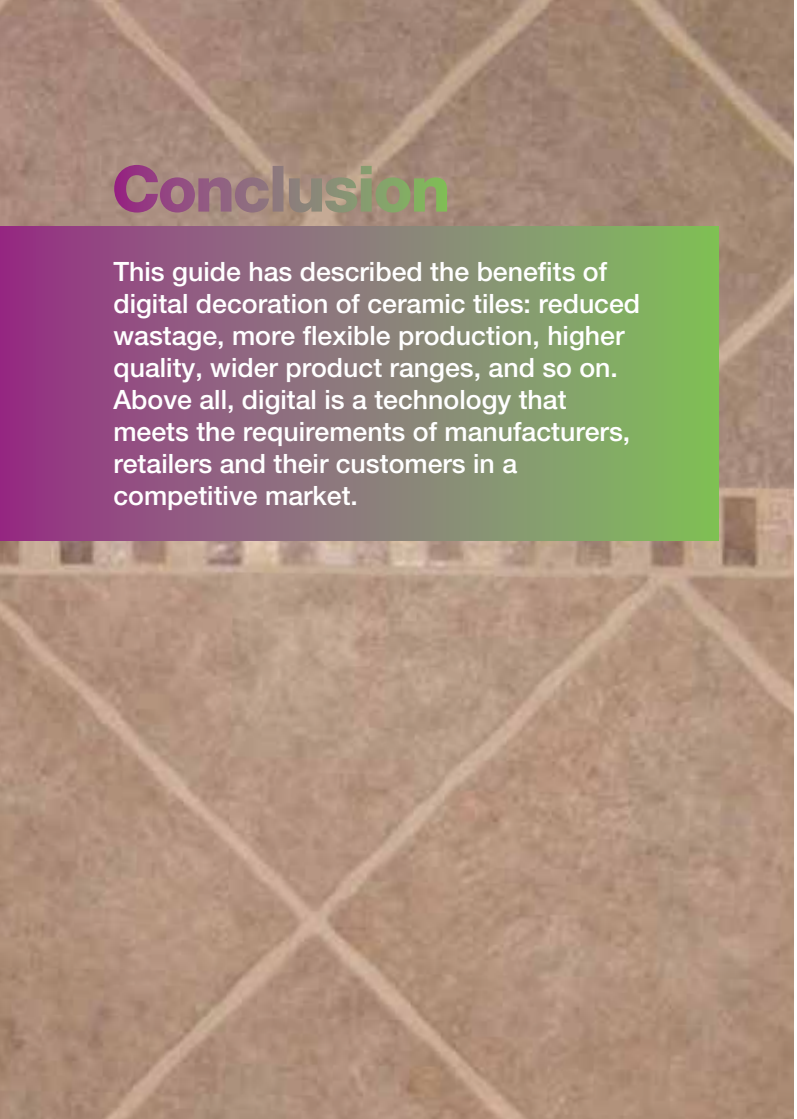
In the future a large-volume digital printing technique could also be used to add technical coatings to tiles – for example non-slip, antibacterial, water repellent or other coatings. It could also make tiles more functional by embedding conductive elements to make sensors for alarms, lighting or other systems.

At Xaar we are also working to improve the decorative patterning of tiles by working with our ink partners by extending the colour space of ceramic inkjet inks. There are a number of challenges to overcome. High kiln temperatures limit the types of pigments that can be used and they have to be non-toxic. In addition, DoD printheads have internal dimensions measured in tens of microns, which means that the pigments have to be delivered in a liquid and the particle size must be carefully controlled to avoid blocking the channels and nozzles. In some cases when pigments are ground to a small size their ability to reflect light is restricted, reducing the colour space that can be achieved with digital inks compared to screen printing ink which are large particle pastes. However, these challenges haven't stopped the spread of digitalisation in ceramics.

There are two ways to improve the final colour achieved by digital printing. The first is to increase the amount of ink laid down by the printing process, which was the main reason Xaar introduced the Xaar 1001 GS12 and its successor the Xaar 1002 GS12. Where the Xaar 1002 GS6 printheads could lay down up to 10 g/m^2 per colour (ie, 50 g/m^2 on a five-colour tile), the 12-84 pL drops of the Xaar 1002 GS12 are capable of laying down up to 20 g/m^2 per colour, significantly improving the colour that can be achieved.

There is a trade-off to be made of course – larger drops are more visible to the eye – which is why the Xaar 1002 GS6 remains a popular choice when fine detail is required in, for example, wall tiles that are often viewed from a closer range.

Xaar extended this principle with the new Xaar 1002 GS40, which can jet drops ranging from 40 to 160 pL. This further increases the fluid laydown to up to 40 g/m^2 per colour – close to the capability of rotary screen printers – and has a significant impact on the colour gamut that can be achieved. This large-drop printhead can also be used to add decorative glazes to tiles, replacing the single roller printer sometimes used to add these after the decoration stage of the production line. This brings all the usual digital benefits – reduced set-up time and costs, the ability to change the glaze effect as often as required – and significantly enhances the range of creative effects that can be achieved on the tile. For example, we are seeing more 'fusion' designs, where natural materials are mixed with modern overprints.



Conclusion

This guide has described the benefits of digital decoration of ceramic tiles: reduced wastage, more flexible production, higher quality, wider product ranges, and so on. Above all, digital is a technology that meets the requirements of manufacturers, retailers and their customers in a competitive market.

These benefits are not expensive. A typical digital decoration printer can be paid for in less than six months of ceramic tile production, and so the investment is not difficult to justify. In addition, digital is simple to integrate into existing lines, and so disruption to production is minimal.

The arguments for digital are compelling, which is why digital inkjet ceramic tile decoration printers are rapidly becoming the dominant decorating technology. Combine the prospect of digital printers that can apply structure and relief as well as decoration with a global ceramic tile market that is currently growing at around 6%, and the opportunities are huge for those companies who embrace digital decoration.

A typical digital decoration printer can be paid for in less than six months

To grasp the opportunity it is necessary to choose the right digital inkjet printhead technology, and this is Xaar's TF Technology™ and HSS™ architecture. Xaar printheads – with their ability to jet a variety of fluids onto a range of substrates, are having a dramatic and transforming effect on many different market segments. As well as ceramic tile decoration, they are being used to reshape manufacturing processes in a wide variety of applications, including labels, packaging, direct to shape and laminates, as well as advanced manufacturing applications which require printing with specialist fluids – for example, flat panel screen displays, solar cells, and semi-conductors.

Continuing developments in printhead technology will further advance digital decoration. Xaar will continue to work on delivering higher speeds, more colour and more special effects – enhancements that will enable innovative manufacturers to extend their creativity in tile design even further. Digital is freeing the ceramic tile industry to explore new frontiers in a market with almost limitless potential.

Xaar ceramic ink partners

Xaar works in partnership with leading ceramic sector ink manufacturers to develop and approve the widest range of compatible inks, specifically matched to the Xaar 1002 printheads. These collaborations deliver a comprehensive range of high-performance inks optimised for use in the demanding ceramic tile decorating environment.

China Glaze

Based in Hsinchu City, Taiwan, China Glaze is Xaar's first Asian ink partner in the ceramics sector. The company, part of the China Glaze Group, has supplied the ceramics industry for over 40 years and is one of Asia's largest producers of ceramic colours, glazes and frits, with a turnover of $200 million. China Glaze employs 800 people across five production facilities in China, Taiwan and Indonesia.

www.china-glaze.com.tw

Xaar works in partnership with leading ceramic sector ink manufacturers

Colorobbia Italia

Gruppo Colorobbia, Sassuolo, Italy, supplies semi-processed materials used in production in all sectors of the ceramics industry. Colorobbia's CINKS range of inks for digital decoration is characterised by high stability and excellent colour performance and comprises blue, deep blue, brown, beige, yellow, black, pink, green and white. The company's C-Shine range provides distinctive colour, texture and surface effects, including metallic and iridescent finishes. C-Shine inks can be applied to both glazed and non-glazed tiles, and are compatible with Colorobbia's standard range of inks. They do not require specific firing cycles or particular glazing applications.

www.colorobbia.it

DEF

With a product range including frits, glazes, screen printing pastes and dyes, DEF have recently developed and introduced digital printing inks for ceramic tiles. Their manufacturing is based in Fiorano in Italy and they focus not only on their domestic European market, but also have an increasing presence in North Africa, the Middle East, India and Russia.

www.defspa.it

Esmalglass-Itaca

Spain's Esmalglass-Itaca, the result of the 1999 merger of Esmalglass and Itaca, is recognised as a pioneer in ceramic pigments, glazes, frits and additives. The company employs over 1,000 people and serves all the major international ceramics markets.

The HCR range of inkjet inks combines a wide chromatic range with high print quality, and comprises yellow, beige, pink, blue, brown and black. Advantages of HCR include greater colour intensity, excellent chromatic reproduction, smoothness, and high levels of physical and chemical stability. The inks' colour intensity delivers high contrast and reduced ink consumption.

www.esmalglass-itaca.com

Ferro

Based in Cleveland, Ohio, USA, Ferro has operations in 26 countries and sells in more than 100. The company's expertise lies in particle engineering, colour and glass science, surface application and formulation. Ferro has pioneered a number of technologies in the ceramics, electronics, glass and pigments industries.

In ceramics, Ferro is a leading supplier of glaze coatings and colours. The company's Keraminks® range is available in a wide range of colours and combines the highest definition and contrast with brighter and more uniform colour. Its advantages include a wide chromatic range, high colour intensity, stability and non-toxicity.

www.ferro.com

Smalticeram

Based in Sassuolo, the centre of the Italian tile manufacturing industry, Smalticeram is a leading producer of frits, pigments, glazes and colours, with production facilities in Brazil, Indonesia, South Africa and Spain as well as Italy. The company's Smaltink range, the result of a three-year development programme, has been specially designed for maximum adhesion between the tile substrate and the ink. Comprising 10 colours, Smaltink can be applied to silkscreen-printed bases, neutral backgrounds, and protective, granular and grit coverings.

www.smalticeram.it

SUNIC

SunJet have recently launched a range of digital ceramic inks and glazes through SUNIC, their joint venture partnership with AT Colores and Vidres. With a European R & D and manufacturing operation, they can supply and support their products globally. As one of Xaar's longest established Ink Partners they bring a large degree of knowledge of digital printing, supported by the extensive ceramic experience of their JV partners.

www.sunchemical.com

Wanxing

With their global headquarters based in Taiwan, Wanxing are the leading Chinese ceramic pigment manufacturer and are now marketing their main products globally to 63 countries. They have six production bases in Guangdong, Fujian and other areas with a strong focus on international quality standards. In their position as a leading ceramic ink supplier, they are committed to developing new digital inks and glazes for the Xaar 1002 printheads.

www.wanxinggroup.com

Xaar ceramic OEM partners

Xaar provides OEM customers with the know-how and ability to incorporate an innovative range of printheads, inks and systems & electronics into their solutions to increase the value and functionality of their own products, and minimise the time required to bring products to market. These collaborations deliver integrated end-results that suit each specific application and invariably increase productivity, speed and reliability.

Xaar assist on all aspects of such projects, including making recommendations and training the technical team to use the various components of the development kit. This ensures full understanding of the capabilities of the technology and optimises the functionality and performance for each specific application.

As the leader in ceramic printhead technology, Xaar works closely with all the leading manufacturers of industrial digital inkjet printing systems in the ceramics sector.

Xaar works closely with its OEM partners to deliver increased productivity, speed and reliability

EFI Cretaprint

Spanish manufacturer EFI Cretaprint has been developing decoration solutions for ceramic tile manufacturers for over 15 years and was the first company to develop a digital inkjet machine using the Xaar 1001, and now use the new Xaar 1002 printhead. EFI Cretaprint's principal digital inkjet machines are the Cretaplotter and the new EFI Cretaprint C3 and EFI Cretaprint P3. These are modular systems and use either the Xaar 1002 GS6 or GS12 printhead.

EFI Cretaprint C3 and P3 are available with up to eight printing bars and with maximum printing widths of 700 mm and 1120 mm respectively. The Cretaplotter, used to prepare samples, develop ceramic designs and manufacture special ceramic products, is available with up to eight colours and has maximum print dimensions of 1400 x 700 mm.

The company describes the Cretaprint C3, as 'representing a new generation of inkjet presses.' The Cretaprint C3 features a single chassis able to accommodate up to eight print bars, which are easy to access due to a new slide-bar design and can be independently configured for printing and special decoration effects. A flexible and innovative multipurpose system, the Cretaprint C3 offers over 1.000 customisable settings, from print width to printer direction and ink discharge.

www.cretaprint.com

Hope Ceramics Machinery

Hope Ceramics Machinery has played a significant part in building the Chinese ceramics industry, developing and manufacturing a wide range of products for ceramics glazing applications.

Hope's first products were decoration presses employing a variety of contact printing technologies, but in 2006 the company began working with Xaar to develop a digital inkjet machine. As a result, in 2008 the company introduced the first digital inkjet decorating machine in China – the Hope Jet – which now incorporates the Xaar 1002 printhead. Today Hope manufactures eight different models in the Hope Jet series and counts many of the top ceramic tile producers among its customers, including Marco Polo, Nabel and New Pearl. The company exports to more than 20 countries.

Hope Jet machines have maximum print widths ranging from 300 mm to 1050 mm and maximum output speeds of 24 m/min. All machines use the Xaar 1002 printhead with its Hybrid Side Shooter™ (HSS™) and patented TF Technology™. These technologies provide high levels of reliability and stability in the harsh conditions of the ceramic tile production environment.

www.fshope.com

Intesa-Sacmi

Italian manufacturer Intesa-Sacmi is a relatively new supplier of digital ceramic decorating solutions (founded in 2010) but in a short time the company has gained a reputation for machines that deliver high performance and reliability at a reasonable cost.

Intesa-Sacmi incorporates the Xaar 1002 printhead in the third-generation, high-definition COLORA HD BLACK Series launched in May 2013. The COLORA HD BLACK is available in four, five and six colours with a range of print widths from 697 mm to 1675 mm. The maximum production speed is 48 m/min. Innovations include new IDRA ink supply and recycling systems, extractible colour bars, more effective cleaning processes, new machine control and management software, and a double-suction unit.

The Xaar 1002 printhead is critical to the COLORA HD BLACK's performance. Xaar's Hybrid Side Shooter™ (HSS™) and patented TF Technology™ provide high levels of reliability and stability, while the Xaar 1002 GS12 delivers larger 18 to 84 pL ink drops for double the colour intensity and bolder tile effects. Alternatively, the Xaar 1002 GS12 can print at twice the speed of the GS6 for higher throughput.

www.intesa.sacmi.it

Keda

Keda Clean Energy is the world's largest supplier and integrator of equipment for every stage of ceramic tile production lines. Like Xaar, Keda's strategy is the digitalisation of the full end-to-end manufacturing process and, as a result, has chosen Xaar printheads as the core technology for its new DPG range of digital tile decoration printers. The first 700mm-wide DPG model made its global debut in 2014 in China.

www.kedachina.com.cn

KERAjet

KERAjet, Spain, has a long history of manufacturing digital inkjet printers. In 2000 the company's first digital ceramic decoration solution won the prestigious Alfa D'Oro Award, presented by Spanish Ceramic and Glass Association to recognise the most important innovations in the ceramics sector.

The modular KERAjet K700 and K1400 systems are available with up to 12 removable colour bars. The maximum print width is 1400 mm and the maximum output speed is 90 m/min. Other features provided by the Xaar 1002 printheads include integrated ink circulation, automatic self-cleaning and optimised ink use, ensuring maximum efficiency and a rapid return on investment.

www.kerajet.com

Meijia Ceramics Equipment Co.

Located in China's 'Ceramic Capital', Foshan City, Meijia Ceramic Equipment Co has been a leader in the development, design and manufacture of ceramic tile manufacturing equipment since its foundation in 1992.

In 2009 Meijia began working with Xaar to develop a new capability in digital inkjet ceramic printing. The result was the launch in 2011 of the Digital Carnival series of digital ceramic inkjet printers, incorporating the Xaar 1001 and now the new Xaar 1002 printhead. Among the features of the Digital Carnival printers are automation, reliability, and ease of operation.

There are eight models in the Digital Carnival DP-X inkjet printer series, all of which incorporate either Xaar 1002 GS6 or GS12 printheads, depending on the different requirements of each customer. The Digital Carnival DP-X printers are available in print widths from 350 mm to 1120 mm and feature high resolution for sharp images, rich colour, and stable performance. Automatic printhead vacuum cleaning allows each printing bar and printhead to be cleaned in less than one minute, either independently or altogether, making for simple operation and maintenance. During printing, there is no need to stop the line to reload patterns, so seamless non-stop image changes enhance production efficiency.

www.mjtj.com

New King Time

China's New King Time has specialised in ceramic manufacturing equipment since 1993, providing a full range of services that include designing production lines, technology consulting and training.

New King Time introduced its first digital inkjet decorating solution in 2011, and added a second-generation model in 2012. Both machines incorporate the Xaar 1002 printhead family. Currently four machines are available, providing print widths from 350 mm to 1040 mm. Four colours are standard, with the option of six colours, and the maximum output speed is 54 m/min.

www.nkt.com.cn

SiTi B&T

SITI-B&T Group's Evolve digital inkjet decorating solution was launched in 2008 in two print widths – 350 mm and 700 mm – to provide the ceramics industry with an industrial-strength inkjet printer capable of handling a variety of fluids and producing short runs of bespoke tiles cost-effectively. Both machines print at up to 25 m/min at 360 dpi resolution and eight levels of greyscale, giving an effective resolution of over 1000 dpi and creating amazingly lifelike images.

www.siti-bt.com

SRS (Assodigit)

S.R.S. SpA was established in 1977 It is a world-leading company in the supply of design and engraved silicone rollers, as well as in the production of screens for serigraphic printing, different printing tools for ceramic tiles decoration, and consulting services on Italian design for customized solutions.

Supported by an innovative and dynamic research team and great expertise in product development, S.R.S. matches technical knowledge and exclusive technology with global original printing solutions and a consulting service for ceramic factories all over the world.

www.grupposrs.com

TecnoFerrari

TecnoFerrari, Italy, designs and manufactures advanced systems for product and process control in the ceramics industry. Initially known for its ColorJet digital inkjet decorating solution, TecnoFerrari launched its successful VivaJet model in 2011, initially featuring the Xaar 1001 GS6 printhead. Available in three models and with up to eight colour bars, the VivaJet prints at up to 70 m/min.

After selling over 200 VivaJets in less than two years, TecnoFerrari launched a VivaJet with the Xaar 1001 GS12 printhead at Tecnargilla in September 2012 and sold over 50 machines in the first six months. Sales have been strong in all markets, but especially in Italy, India and the Middle East, where ceramic manufacturers have taken to the VivaJet's combination of compact design, simple operation and reliability.

TecnoFerrari now offer all their printer models with the Xaar 1002 family of printheads. TecnoFerrari has recently released new printer management software that further enhances the VivaJet's performance and flexibility and improves colour management. A key feature of the software is faster data transfer, which speeds pattern changes so that test tiles can be printed without interrupting production. Image processing has also been optimised to minimise ink consumption and reduce costs.

www.tecnoferrari.it

TSC

TSC, established in 1989, is a leading Italian company specialising in the production of technologies for ceramic tile glazing and decoration. After an acquisition of a major brand in 2002, TSC was able to offer the market a complete plant for third firing and special pieces creating tailor made solutions to customer specifications.

TSC prides itself on their continuous investments in new technology research. During the last two years, TSC has invested in the digital sector developing and installing its I.PIX machines which have received excellent customer feedback because of the innovative technology incorporated.

Glossary

Acoustic wave: The pressure wave created in the ink within a printhead to eject drops. *See also waveform*.

Apparent resolution: The visually-equivalent resolution of an image printed with greyscale (variable drops), compared to the same image printed with binary drops.

Array: An arrangement of individual inkjet printheads mounted across and/or along the substrate path. Often a set of printbars populated with multiple printheads mounted across the substrate transport.

Binary inkjet: Binary printing means the drop is either there or it is not and only one drop size is possible so all drops are the same size, as opposed to variable-sized drops used in greyscale printing.

Biscuit: The name given to the ceramic tile body moulded under high pressures. The press gives the ceramic tile its size, shape and, in the case of digitally-decorated ceramic tiles, its texture. As its name suggests, the biscuit is extremely fragile and prone to breakage during the traditional screen printing process. Also sometimes called ‘bisque’.

Chamber: In a printhead, this refers to the ink-filled cavity created in the actuator immediately behind the nozzle or nozzle plate.

Channel: The pathway through which ink flows. *See also chamber*.

Colour gamut: The complete range of colours reproducible from a printing system on a specific substrate.

Continuous inkjet (CIJ): A system where there is a continuous flow or stream of ink from a pressurised reservoir. This is broken up into droplets which are deflected by applying a varying electrostatic field to form an image.

DoD (Drop-on-Demand): Printheads that only produce ink drops when required.

DPD (Drops Per Dot): The number, or maximum number, of sub-drops in a printed drop. *See also grey levels*.

DPI (Dots Per Inch): Measure of the regular spacing of dots printed on the substrate. Sometimes incorrectly used as measure of resolution.

Drive electronics: Hardware and software products to enable the image to be sent as electrical signals to the printhead; usually split into several modules (printhead, Head Personality Card and Drive electronics) which interfaces with a PC. Xaar makes the XUSB drive electronics and HPC systems components.

Drop placement accuracy: The accuracy with which a printhead can place a drop. Typically measured in milliradians, or microns at 1mm print distance and stated as a typical or statistically valid measurement (e.g. +/- 5um at 3 sigma).

End-shooter: A printhead with a nozzle orifice through which the ink is ejected at the end of each channel.

Firing: The event that causes the ejection of the droplet from the printhead. Also, the final baking stage of ceramic tiles in a kiln after printing.

Frits: The main component of a ceramic glaze. A glaze is usually made up of one or more frits with the addition of, where necessary, raw materials, pigments, salts, etc.

Glaze: Matt or gloss coating applied to the biscuit prior to decoration. Glazing serves both practical and artistic purposes, providing aesthetic beauty, water repellence, durability, and hygienic properties.

Grey levels: The number of discrete density levels in an image, typically 256 levels, represented as an 8-bit binary number. In inkjet printing, 2, 4, 8 or 16 grey levels are typically used, together with error diffusion, to simulate a continuous tome image. The number of Drops per Dot (DPD) is one less than the number of grey levels, and zero is also a grey level.

Greyscale: A scale that shows the steps of increasing colour density (grey levels,) from light to dark, of the grey levels. A greyscale printhead can print variable-sized drops from the same nozzle.

Head Personality Card (HPC): The HPC allows the connection of different heads to a set of common drive electronics. It converts the generic information from the drive electronics into the specific signals that the particular printhead type requires.

HSS™: Xaar's Hybrid Side Shooter™ technology. Two acoustic waves moving through the channel in an actuator meet in the middle and cause pressure changes that fire a drop out of the side of the channel. The drop is forced downwards through the inkjet nozzle, the nozzle being on the side of the channel, not at the end.

Hybrid Side Shooter: In a Hybrid Side Shooter printhead, the nozzle is at the side of each channel.

Image resolution: Resolution quantifies how close lines can be to each other and still be visibly resolved. However, it is often taken to mean the number of pixels per unit length of image: for example, pixels per inch, pixels per millimetre, or pixels wide.

Kiln: A thermally insulated chamber where the tiles are fired or baked.

Ink recirculation: Ink recirculation keeps the ink in constant motion, preventing sedimentation and nozzle blocking. This is essential when printing heavily-pigmented, highly-viscous ceramic decoration inks. *See Xaar TF Technology™*.

Natural or native resolution (natural dpi): The number of nozzles per inch on the printhead (npi).

Non-contact printing process: A process in which there is no contact between the substrate and whatever applies the ink. In digital inkjet ceramic decoration the distance between the substrate (the ceramic tile) and the printhead is generally 3-5 mm. This means that no mechanical pressure is put on the ceramic tile, and breakages are rare. Non-contact also means that digital inkjet printers can print on 3D surfaces to create textured tiles.

Nozzle: In an inkjet printhead the nozzle is the carefully shaped hole from which the ink is ejected.

Pico: One-millionth of a millionth of the base unit or 10^{-12}.

Piezoelectric effect: The effect of generating electricity when mechanical stress is applied to certain materials, which change shape under the influence of the electric field. Exhibited by certain ceramic materials, such as PZT (lead zirconate titanate).

Pigment: A class of colorants used in inks, paints, etc., where the colour is provided by the absorption or reflection of light by these small particles suspended in a carrier.

Pixel: The smallest image-forming unit of a display screen.

Prime: The act of initially introducing ink to an inkjet printhead and forcing ink out of the orifices to expel air from the chamber or the ink manifold. Done prior to printing to ensure the printhead is ready to print.

Print distance: The distance from the inkjet printhead's nozzles to the printing surface (substrate).

Printbar: Precisely-aligned number of printheads in a single mount. *See array*.

Printhead: The section of an inkjet printing system that generally contains multiple nozzles for jetting the ink.

Purge: To force ink through the printhead to clean out any accumulated debris or air.

Resolution: Resolution is a function of the smallest dot in the printed image. The smaller the dot the higher the resolution as it is the ability of the eye to resolve separate dots that matters.

Roof mode: In a roof mode piezoelectric printhead a piece of piezoelectric material is glued to the roof of a chamber. The drop of ink is ejected when a voltage is applied to the piezoelectric material, causing the roof to deform and push the drop of ink out from the nozzle.

Screen printing: The traditional printing process used to decorate ceramic tiles. Screen printing is a contact printing process in which each colour is applied by a separate roller.

Shared wall: The technique, patented by Xaar and licensed to other printhead manufacturers, of increasing native resolution by using the same piece of piezoelectric material to actuate adjacent channels.

Shear mode: In a shear mode piezoelectric inkjet printhead (such as the Xaar 1002 GS6 and Xaar 1002 GS12) the electric field is applied perpendicular to the polarisation of the material. This causes the piezoelectric crystal to shear, not to lengthen or shrink.

Sub-drops: The small droplet that join together to make up a single, variable-sized drop in greyscale printing.

Substrate: A term describing any surface to be printed on.

Throw distance: *See print distance*.

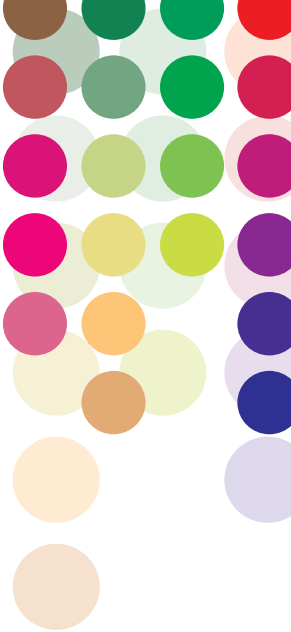
Variable drop: Creating variable drop sizes yields higher apparent resolution. *See also greyscale*.

Viscosity: The physical property of fluids to resist flow. In general, ink viscosity increases with decreasing temperature. The normal unit of measure in viscosity in the metric system is poise, but with digital inks it is centipoise.

Waveform: The electrical drive signal applied to the PZT wall actuator within a piezo printhead to produce an acoustic (pressure) wave in the channel.

XaarDOT™ (Xaar Drop Optimisation Technology): Encompasses binary and greyscale drop formulation options.

Xaar TF Technology™: Xaar's unique TF Technology™ – the only true ink recirculation system – enables the ceramic ink to flow across the back of the nozzle during drop ejection, carrying any particles or trapped air bubbles away from the ink path, not forcing them into the nozzle. This means nozzles are continuously primed and kept blockage-free, ensuring that the printhead is fully operational for the maximum length of time. *See also ink recirculation*.



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