Digital Printing of Packaging – The Tonejet Solution

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Abstract

Tonejet is a digital printing technology based on electrostatic ejection. The technology has been commercialized for metal packaging and is being applied to a wide range of packaging applications. In this paper we describe recent developments of Tonejet Technology focusing particularly on those aspects that enable Tonejet to meet the challenges of digital printing of packaging.

Economic pressures are continuing to drive packaging to adopt digital printing processes such as Tonejet; in this paper we describe the advantages and challenges of shifting from conventional printing to digital in the packaging area.

Environmental pressures also require that decoration technology is capable of printing directly onto new sustainable materials. We explain how the electrostatic ejection process behind Tonejet technology enables direct decoration of a wide range of materials, including both non-absorbing and absorbent materials.

We also focus on the scalability aspects of Tonejet, including the use of scalable printhead fabrication processes, and the technical aspects that enable the combination of multiple printheads into wider units. Together these allow Tonejet to meet the dimensional and throughput requirements of packaging printing.

The market for printed packaging

Printed packaging has grown steadily over the last five years, despite the global economic downturn. The total area of packaging printed has grown at an annual rate of 1.5% in the last five years; this contrasts with a decline in the total area of printed material produced across all markets, with some two trillion fewer A4 pages being printed in 2011 compared to 2006, equivalent to an annual decline of almost 1% [1].

Digital print continues to expand, growing at an annual rate of almost 5% over the last five years, although despite this, barely 2% of all print is digital. Drivers for digital include the cost savings realized by the simplification of the printing process, and the demand for reduced run lengths due to greater need for regionalization and hence customization. This is particularly true in packaging, where typical run lengths continue to decrease due to the growing need to customize global products for specific regions as well as the introduction of niche and sub-brands.

The combination of the sustained growth in package printing, coupled with the drive to digital printing means that digital printing of packaging will continue to be an area of innovation and growth.

The Tonejet Process

Tonejet is a non-contact, digital printing technology based on electrostatic ejection of fluids containing charged colorant particles. The technology is particularly suited to the demands of the packaging sector where throughput, quality, low cost per print and reliability are key requirements.

The Tonejet print head consists of two main components:

- The Ejector Array is a set of fluid supply channels and pointed ejectors, each carrying an individually addressable electrode. The structure creates the required three-dimensional shapes of the ink meniscus and electric field required for controlled ejection.
- The Front Plate is a metalized plate with a single slot through which the ink passes onto the substrate. This isolates the ejecting part of the printhead from the external environment.

The Tonejet printhead components are shown in figure 1.

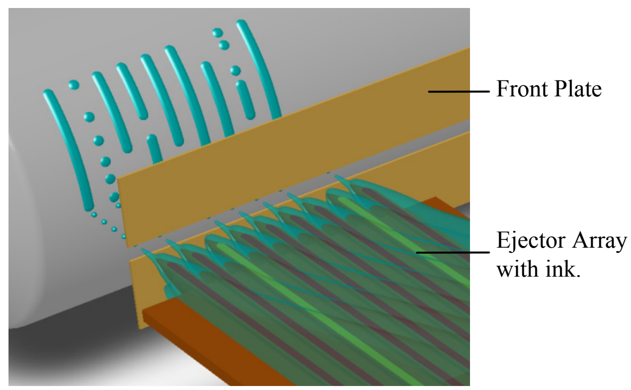

Figure 1*. Schematic diagram of a Tonejet printhead showing the two main components. The 'red' ejectors have a voltage applied such as to cause ejection.*

Ink flows continuously over the Ejector Array such that there is always a fresh supply in the ejection region. The ink is a suspension of charged solid colorant particles. Application of a positive voltage to an electrode causes these charged particles to move to the ink surface at that particular ejector; when sufficient voltage is applied to exceed a critical electric field, the meniscus moves forwards and ejection occurs. The duration of the ejection is controlled by the duration of the voltage pulse, thus enabling grayscale control, where the volume of ink ejected within a pixel is controlled digitally. The duration of the pulse voltage can be controlled accurately, leading to a high degree of control over the ejected volume. This not only gives exceptionally high image quality but provides an improved method of stitching printheads together as described in this paper.

Application for beverage cans

Tonejet is focused on packaging applications; the first commercial product, a digital beverage can printer, (figure 2) has been embedded within an existing Ball Packaging Europe beverage can production plant, and runs in parallel to the conventional printer.

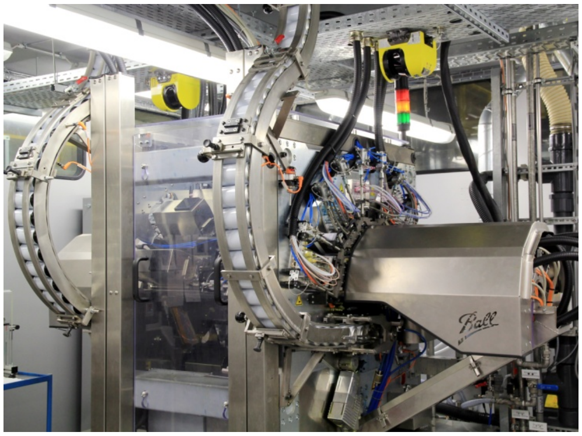

Figure 2. The Tonejet digital can printer.

The line is integrated so that digitally printed cans undergo the same down-stream processes as the conventional cans as shown in figure 3.

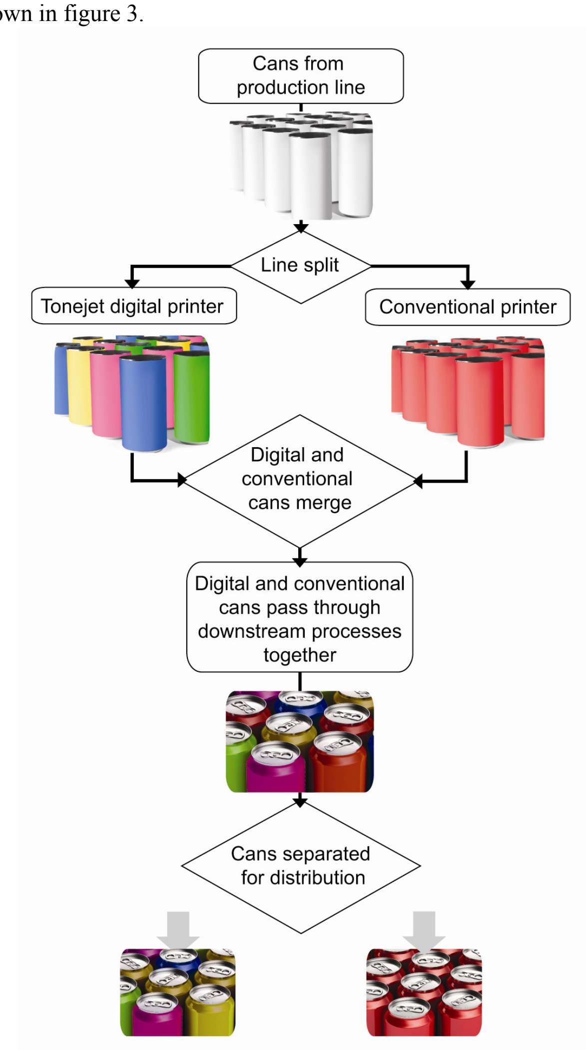

Figure 3. Flow chart showing the Tonejet digital can printer within an existing conventional can production plant.

This approach maximizes the efficiency of digitally printed beverage can production. This was possible because Tonejet technology meets the requirements of throughput, up-time, and reliability required for integration into an existing plant.

Beyond beverage can printing

The Tonejet process has a number of inherent qualities that make it ideally suited for printing packaging in general:

- The final print consists of a very thin layer of pigment particles; less than 300nm per solid layer of color.
- The low ink cost and low ink consumption due to sub-micron film thickness, leads to low running costs.
- Food grade ink components give straightforward application in food packaging, and in particular can be used for primary packaging applications.

These features of Tonejet will be exploited for application of the technology beyond beverage can printing. For example, the thin ink layer is critical for beverage can printing, as it ensures the print survives forming; this feature will also be important for other substrates which are flexed during post-print processes or in use. The low ink volume enables Tonejet to print on a very wide range of substrates including both non-absorbing substrates such as metal and plastic films as well as highly absorbent papers and carton board.

For non-absorbing substrates, the relatively low level of fluid ejected results in a low spread of ink on the substrate giving high image quality. For absorbing substrates, the solid particles are held near the surface, giving vibrant, high quality images. This ability to print onto a wide range of substrates will become increasingly important as new substrates are introduced, for example, for reasons of sustainability.

A key consideration when planning a shift from conventional printing to digital printing is the location within the supply chain where printing should and can occur. The conventional approach of producing packaging in centralized locations which is then shipped to the point of use generates waste due to losses in shipping and storage. Moreover a proportion of printed packaging is never used, as printers over-produce to avoid the high cost of repeat short runs.

For many packaging applications it will be possible to exploit the benefits of digital printing fully by implementing digital printers on or very close to the final production line. This maximizes the benefits of digital printing, such as ‘print what you want, when you want it’, allowing just-in-time response to external events to be fully realized, as the packaging is finished just before it is used.

Tonejet is able to support both approaches. It can be used by centralized converters producing packaging for many different applications, or for printing on or near the production line. Of particular importance for the latter are Tonejet’s use of food grade ink components and throughput capability.

Tonejet – a scalable technology

For a digital printing technology to be adopted in the packaging market, it must be able to meet the throughput required. In practical terms this means that the print heads must span the width of the substrate to enable single pass printing. In general it will not be practical to introduce a scanning system into a production line as the required line speed will not be achieved.

Scalable fabrication processes

In developing Tonejet, we have adapted scalable fabrication processes for making printheads. Using this approach, Tonejet has produced heads of 42mm, 105mm and 172mm width and is actively developing a yet wider printhead. For example, the ejector array component is made using a replication technique, whereby a highly accurate master is made, and the final component is then produced from moulds made from the master. In this way, the time taken to produce the printhead structure is independent of the number of ejectors.

A similar philosophy has driven the development of all the printhead fabrication processes and so, for example, metal electrodes are deposited on to the printhead structure using lithographic techniques developed for the semiconductor industry. These processes are based on photo-resist and masks and, as for the component replication, the time required to form electrodes is independent of printhead width.

Finally, the front plate component contains a single slot, common to all ejectors; as with the other components, the fabrication complexity does not increase with increased width.

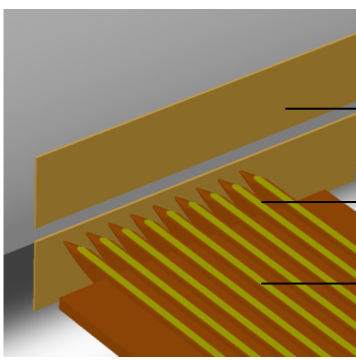

Figure 4. *The processes used to make the Tonejet printheads are scalable; the time taken for fabrication processes is independent of printhead width.*

By driving up the yield of the fabrication processes we are able to produce wide heads that are capable of spanning the substrate for many packaging applications.

Scalable print width

Clearly for some applications, the printed width required will be beyond the practical limit of a monolithic printhead. In this case, Tonejet uses multiple print heads to span the substrate.

When stitching printheads across a substrate, avoiding a visible join in the print where printheads abut can be a significant challenge. In particular, maintaining accurate alignment between neighboring print heads is generally necessary to avoid visible print artifacts such as dark or light lines at the join.

Overlapping, rather than butting the printheads enables the join to be better hidden as a given pixel within the overlap region can be printed by one printhead or the other. A number of such binary interleaving strategies can be used: (i) changing the position of the join during printing; (ii) distributing the join spatially between the two printheads; or (iii) a mixture of the two. Binary interleaving strategies can help to hide edge effects by distributing them over an area, but they are sensitive to printhead misalignment.

Although these strategies for printhead stitching can be used by Tonejet printheads, we have also developed a method which takes advantage of the ability to continuously control the volume of the ejectant. This unique 'volume control' method is used to progressively reduce the ejection strength at the edge of one head whilst increasing the strength of the adjacent overlapping head.

In this way, the join between two printheads is blended and this has given better results, particularly where there is misalignment between heads. This is illustrated in figure 5.

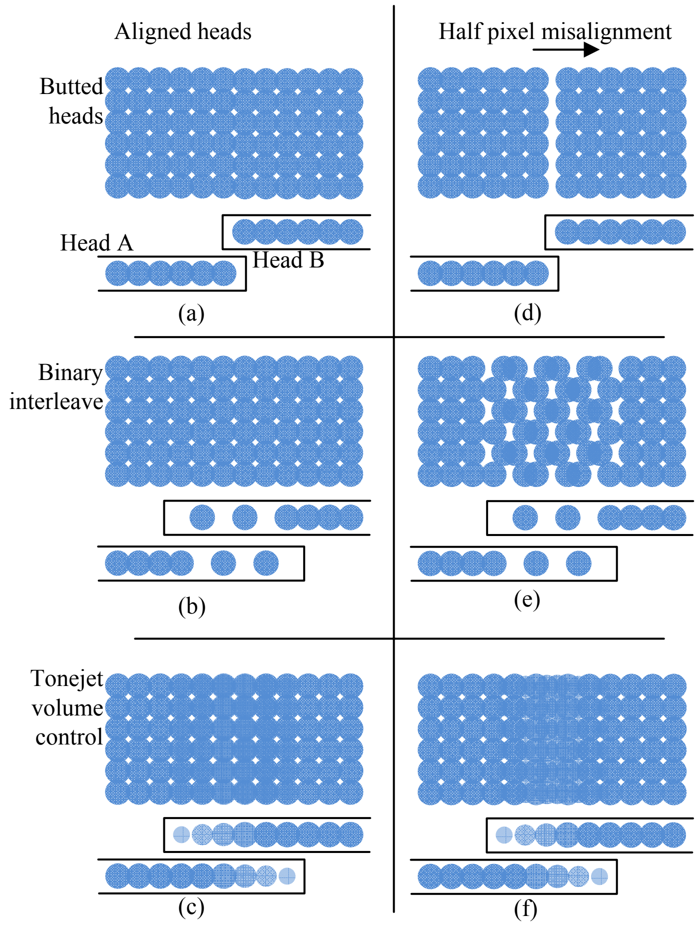

Figure 5. *Schematic diagrams of an overlap region between two stitched heads, A and B. (a) – (c) are for perfect alignment of the heads. (d) – (f) shows the results for heads misaligned by half a pixel.*

The sections at the bottom of each diagram show the output of the two printheads individually. The combined result is shown at the top of each diagram. Diagrams (a) - (c) are for two heads perfectly aligned. Diagrams (d) – (f) are for two heads misaligned by half a pixel. Diagrams (a) and (d) are for two heads that are butted, with no distribution of printing across the join between the two heads. Diagrams (b) and (e) show an example of binary interleaving, where alternate pixels are printed from different heads. Diagrams (c) and (f) show the Tonejet volume control method. The volume control method is more resilient to slight misalignment between printheads and substrate wander, because, with this method, misalignment of pixels does not create gaps between pixels or doubly printed pixels in the stitch region, both of which can create highly visible defects in the binary methods.

Figure 6. *Print samples in which the volume control method has been used to stitch print swathes.*

Figure 6 shows two print samples, stitched using the volume control method described above. The stitching regions run vertically through the full height of the images in the positions indicated by the black bars.

Summary

In this paper we have described Tonejet digital printing technology, and how it is being applied to packaging applications. Tonejet's first commercial application is beverage can printing, in which digital printing is integrated into existing beverage can production.

We have presented the key qualities of Tonejet; in particular, the low ejected ink volume and thin ink layer, which are essential to Tonejet's ability to print onto a wide range of both absorbing and non-absorbing substrates.

We have also considered the changes in production required to fully exploit the advantages of digitally printed packaging, and shown that Tonejet is capable of being placed in either a centralized package production location, or on or very close to the final product packaging line.

Finally we have highlighted the scalability of Tonejet. Scalable fabrication processes are used to make the printheads allowing printhead sizes that will span the width of many substrates. In addition, the unique control that Tonejet has over the ejected ink volume provides a printhead stitching method for wider substrates that is resilient to head alignment and substrate wander.

References

[1] The Future of Global Printing, Market Forecasts to 2016. Pira International Limited.

Author Biography

Daniel Mace has been directly involved with the development of Tonejet technology since its inception. He lead the Tonejet printhead programme during the printhead development phase, and was responsible for developing the head fabrication processes that are used in Tonejet's products. He also played a lead role in the development of Tonejet's first beverage can printer. Today, Dan leads the Technology Team at Tonejet Ltd.

Dan holds a PhD in Physics from the Cavendish Laboratory, Cambridge.