Where next for industrial digital printing?

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Abstract

At present, there are two dominant technologies for the digital deposition of liquids: inkjet and valvejet. Both have very different ejection mechanisms and each has very different technical specifications. As a result, they are exploited in very different applications. Inkjet is used where high image resolution and small droplets are required, leading to its adoption in surface decoration, digital document presses and the like. [1] The construction of inkjet printheads, and the fundamental physics of droplet formation, prevent its use with viscous or sedimenting inks In comparison, valvejet is a far cruder technology as the droplets are much larger, the firing rate is lower and the nozzle density is low. Array versions of valve-jet were initially developed for carpet decoration and it is best suited to applications where the print resolution doesn't need to be high. Unlike inkjet, valvejet printheads are capable of processing viscous fluids.

There is thus a large capability-gap between inkjet and valvejet. As a result, in a wide range of applications where there is a demand for accurate digital deposition of viscous materials, no solution is readily available. In this paper, we show that TTP's Vista Inkjet technology is ideally suited to many of these applications, and provide an initial estimate of the market demand for such a solution.

Discussion

Quantitatively, when one compares the specifications of the two main digital, drop on demand technologies – industrial inkjet and valvejet – there are about two orders of magnitude difference in performance. This is true for nozzle density, droplet size and firing rate, for example. The one huge advantage that valvejet has over inkjet is in the range of fluids it can eject. Whereas inkjet is limited to Newtonian inks with a low viscosity containing sub-micron particles (so that they remain in a stable suspension), valve jet can print fluids with a much higher viscosity because the pressure generating mechanism is independent of the ejection mechanism.

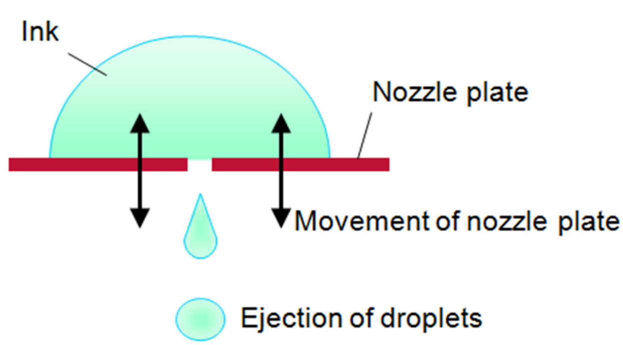

Figure 1: a schematic showing the basic ejection mechanism of TTP's moving nozzle technology.

The difference in capability – and therefore applicability – between inkjet and valvejet is therefore huge and there are many industrial printing applications for which neither technology is ideal. This includes those applications for which a functional fluid cannot be reformulated so that it can be ejected through an inkjet head without losing the desired functionality. As a result, applications as diverse as 3D printing, footwear manufacture, textiles, packaging, automotive painting and the like, all of which have strong drivers for a digital technology, are struggling to move forwards. This creates an opportunity for a new technology to establish itself.

A droplet-generating technology of the type invented by TTP, which was first described as a single nozzle, circular device over 20 years ago, is one solution that could be ideally suited to address this opportunity. [2] The basic mechanism for the ejection process is shown in schematic form in Figure 1.

Over recent years, TTP has modified the basic device architecture to provide a linear array of independently addressable nozzles: an inkjet printhead, which we call Vista Inkjet. The main advantages that have been demonstrated are the ability to eject a wide range of materials including shear-thinning rheologies and inks that have large, sedimenting particles. A detailed discussion of the basic physics and technology is described elsewhere. [3] A photograph of a prototype Vista printhead is shown in Figure 2.

Figure 2: a laboratory prototype of an industrial inkjet printhead with TTP's moving nozzle technology, including drive electronics.

Table 1 shows a summary of the comparison between industrial inkjet, valvejet and Vista Inkjet, underlining the differences between each technology. This table shows that Vista Inkjet has properties that fill the gap between industrial inkjet and valvejet, in terms of nozzle density, drop size, firing rate and ink rheology.

The one area where Vista Inkjet has a clear advantage over both technologies is its ability to print large particles of a type which are heavily sedimenting when formulated into inks. Vista Inkjet has a very open internal structure permitting continuous recirculation of the ink. The ultrasonic motion of the nozzle plate also discourages sedimentation inside the printhead around the nozzles. In contrast, most industrial inkjet and valvejet heads have a 'dead end' architecture such that any sedimentation would immediately result in nozzle blockage. There are exceptions: the SII Printek RC1536 and Xaar 1001-1003 series of printheads allow some recirculation of the ink, but here the particle size is still restricted to less than 2-3 µm. In comparison, we have shown that Vista Inkjet can eject particles up to at least 50µm in size in a heavily sedimenting ink.

	Inkjet	Vista Inkjet	Valvejet
Nozzle density	100s npi	10s npi	1s npi
Drop volume	1s – 10s pL	10s – 100s pL	nL - µL
Firing rate	10s kHz	5-10 kHz	1 kHz
Ink viscosity	Highly restricted: low, Newtonian	Wide range: shear thinning	Extremely wide range
Particle size	Small: stable inks required	Up to 50 µm demonstrated	Small: stable inks required

Table 1: summary of the characteristics of industrial inkjet, Vista Inkjet and valvejet.

Based on the features and benefits described above, Vista Inkjet is ideally suited to applications that are currently analogue, where there is a strong driver for digital, but the fluid cannot be reformulated to be compatible with a commercially available industrial inkjet head (for example, because the desired functionality would be lost).

Examples of materials that can be digitally printed with TTP's moving nozzle technology include engineering polymers for 3D printing, paints, adhesives, some industrial coatings, true metallics, glass frits and large decorative pigments. To the best of our knowledge, none of these materials can be ejected by commercially-available industrial inkjet printheads.

A clear example of an application where there is a strong driver to print a wider range of materials is additive manufacturing. Here, the use of inkjet technology is largely limited to prototyping because the molecular weight of the polymers has to be kept low enough to keep the viscosity within the desired range for inkjet. This in turn means that the resulting printed parts are not strong enough for use in commercial products.

To improve the mechanical properties of printed 3D plastics, one approach that is being explored is to add particulates that are dispersed within the polymer matrix; however, as we have seen, this is not a viable option for conventional inkjet.

Because of Vista Inkjet's ability to print shear-thinning fluids and fluids loaded with particles up to 10s µm in size, it is ideally placed to address these methods of improving the mechanical properties of 3D printed plastic components.

In addition to these benefits, the possibility of true multi-material 3D printing can also be realised by Vista Inkjet.

A second example of an application that is searching for a digital solution is footwear manufacturing. At present, the adhesives that are used to bond the various layers of a shoe together are applied manually, often with a technology as basic as a paintbrush. This is slow, inaccurate, inefficient and stipulates that the manufacturing line must be in a location where labour costs are low. Initiatives such as Industry 4.0 require that this process must be automated to allow re-shoring of the manufacture of these products into territories close to the customers, but this is impossible without automating the deposition of the adhesives. We have previously demonstrated that Covestro's polyurethane-based adhesives can be printed by Vista Inkjet, for example, meaning that this technology could be ideally suited for this application. [4][5]

Other applications are similarly poised to turn digital, if only the right technology existed. In automotive painting, for example, maskless decoration of multicolour cars with zero overspray is highly desired [6], but inkjet cannot eject paint and valvejet is too slow and yields a low-quality finish. In textiles, inkjet is already addressing the decoration of fabric, but pre- and post-processing steps, adhesives and soft coatings require viscous and sometimes particulate loaded fluids that cannot be printed with inkjet.

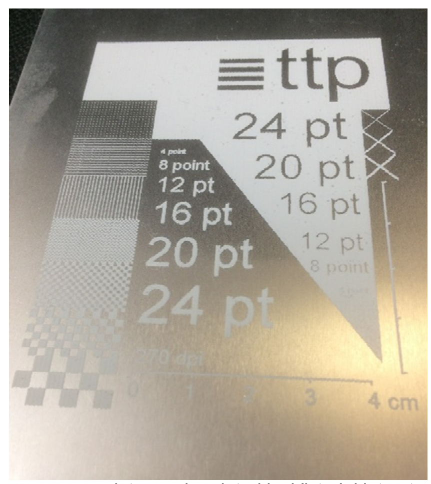

Figure 3: an aerospace paint sample printed by Vista Inkjet onto steel.

TTP has undertaken a review of the above applications with the aim of quantifying the potential size of the opportunity. This was a challenging undertaking, as much of the required data did not readily exist in any format prior to our review. Nevertheless, by talking to a wide range of people in the target industries, including end-users, materials suppliers (formulators and raw chemical manufacturers) and machine suppliers, estimates of the demand have been generated. There is naturally a great deal of uncertainty regarding how quickly and enthusiastically people will adopt any new technology, however by making a careful assessment of the need for digital, combined with the unique circumstances of each individual opportunity, a useful estimate can be made.

Table 2 shows the summary of the results of that investigation. Each row pertains to the applications we have examined to date and each column shows the total number of printheads we believe could be required per annum to satisfy the demands of each industry by a given date. For the purposes of our investigation, we assumed that a Vista head would have a design comprising a single row of 64 nozzles at a spacing of 50 npi, capable of ejecting 500 pL droplets at 5 kHz. These are not fixed properties of the technology and many attributes of a Vista head can be adapted depending on the exact application requirements.

Application	Est. printhead annual volume demand (year)		
	2020	2025	2030
Textiles (pre- and post-treatment)	6,000	50,000	160,000
Footwear adhesives	300	1,200	10,000
Automotive paint	1,500	6,000	11,000
Aerospace paint	2,000	5,000	9,000
3D	7,000	15,000	30,000
Approx. totals	20,000	80,000	200,000

Table 2: summary of estimated printhead volume demands for a variety of applications that TTP believes can be uniquely addressed by Vista Inkjet.

Conclusions

Some interesting conclusions can be drawn from this data. Firstly, although we believe we have been conservative with our estimates, the projected total printhead sales are on the order of 200,000 per annum in 2030, assuming the technology becomes available towards the end of the current decade. In comparison, the current global annual market for industrial inkjet printheads is on the order of 500,000.

Secondly, the two main opportunities for an inkjet technology that can print fluids of the type that can be ejected by Vista Inkjet are likely to be textiles (pre- and post-processing) and 3D printing of engineering polymers. Paints and adhesives for transportation and footwear, respectively, are interesting markets that have strong drivers for a move to digital, but commercially we believe they are likely to be less interesting to a printhead supplier.

Of course, we know that there are many more applications for a technology with the features and benefits of Vista Inkjet, some of which may end up being larger than those we have discussed above. Potential additional areas of interest include security printing, printable electronics and packaging (for example, over varnish and true metallics – see Figure 4). Our analysis of these markets is at an earlier stage than those discussed herein, however it seems likely that these applications are likely to be at least as large as automotive painting or footwear adhesives.

In conclusion, we believe that major growth areas for inkjet printing are likely to be in applications that cannot currently be addressed with existing technology. To address these markets, one must be able to print fluids that retain the desired functionality, which often means fluids with large particulates and complex rheologies. We propose that TTP's Vista Inkjet is ideally placed to address these markets and that the demand in several markets is commercially highly attractive for all parts of the supply chain, including printhead manufacturers and materials suppliers in addition to end users.

Figure 4: a packaging ink displaying a true metallic effect printed by Vista onto plastic sheet (D50~5μm aluminium flakes).

Keywords

inkjet, drop on demand, moving nozzle, TTP, 3D printing, textiles, automotive painting, footwear manufacturing

Author Biography

Dr. Peter Brown has been with TTP for 15 years and is an experienced leader of technical and business development activities with a focus on industrial digital printing. Peter obtained his PhD from the University of Cambridge on the optoelectronics of semiconducting polymers and joined TTP's Printing Technology Division in 2002.

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