Ink Jet Based Wide Format Printing Presses: Architecture and Opportunities

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Abstract

The technologies and markets for medium and super wide-format digital printers are developing rapidly and new solutions are being introduced at an accelerated rate. Ink jet, and specifically piezoelectric ink jet, is emerging as the technology of choice in these high-end digital printing markets.

Presently in this marketplace, the focus is shifting away from the technology itself and towards end-user requirements. Consequently new targeted innovative systems, such as the VUTEk PressVu^{TM}, have emerged. These industrial printing platforms are being developed with new capabilities, such as ability to handle flexible as well as rigid substrates. In addition, higher productivity and higher resolution, as well as more robust and reliable technology, are making these platforms ideal for short-run printing applications traditionally served by screen printers. Ink solutions include a wide range of dye and pigment based formulations designed to work with specific media across a wide range of applications. As a result, the wide format printer manufacturers are leading the way in terms of bringing digital solutions to new markets.

This paper will present the most recent developments in modular piezoelectric printhead technology and printer architectures. In addition, the impact of these unprecedented choices of media, ink systems, print quality, and production speed on the industrial printing industry will be discussed.

Introduction

The early developments of piezoelectric-driven drop on demand printhead technology dates back to the late 1970's. This technology – simple in principle yet complex in implementation – has held the promise of combining low cost manufacturing with high productivity, making it suitable for a broad range of applications and markets. In the SOHO market, Epson has succeeded in making piezo printheads a mainstream technology in a market dominated by thermal ink jet. However in the industrial and commercial printing markets, success has so far been more elusive and applications have been limited by the technical capabilities of the printheads, inks, and printer mechanisms. With the recent technological developments described below, this situation is about to change.

Piezo Printhead Advancements

There are a number of key improvements in piezo printheads which have had an impact on the industrial printing market.

Performance

In terms of performance, wide format printer manufacturers are seeking 4 qualities: sustainable operation at high frequencies, accurate jet trajectories, excellent channel-to-channel uniformity, and wide operating latitudes. To a large extent, the latest generation of piezo printheads meet or exceed these performance requirements, as evident in the specifications for the Spectra Nova 256/80 and the Galaxy 256/20 printheads, shown in Figure 1. In the range of 300 to 400 dpi print resolution with any degree of interlacing, printheads exist with a sustainable throw rate in excess of what wide format printers can utilize due to the limitations of maximum carriage speed. Drop placement errors due to jet angularity deviations, a leading cause of banding artifacts, are easily managed to sub-pixel magnitudes – on par with substrate positioning errors. Significant strides have been made in channel-to-channel drop velocity and mass (volume) uniformity, especially through the reduction in crosstalk, significantly raising the bar for image quality standards for high productivity wide format printers as well as drastically reducing manufacturers' printhead installation and replacement time. The improvements in operating point flexibility can be seen in Figure 2. The green area in this performance plot for the Spectra Nova 256/80 printhead depicts the possible variation in PZT actuation voltage for sustained jetting as a function of frequency. This operation zone is quite wide, even at frequencies as high as 20 kHz. This operation point flexibility can be exploited to accommodate the different fluid properties of inks or to produce different drop characteristics.

	Nova 256/80	Galaxy 256/20*
Number of Addressable Jets	256	256
Nozzle Pitch	0.011" (289 microns)	0.010" (254 microns)
Nozzle Configuration	Inline	Inline
Nozzle Diameter	54 microns	33 microns
Calibrated Drop Mass	75 nanogram	20 nanogram
Drop Mass, variance from mean**	±10%	±10%
Jet Straightness, typical maximum angular error	20 milliradians	20 milliradians
Nominal Drop Velocity	8 m/s	8 m/s
Drop Velocity, variance from mean**	±10%	±10%
Crosstalk, maximum	5%	5%
Operating Temperature Range	Up to 50°C	Up to 125°C
Typical Ink Viscosity Range (at jetting temperature)	10-14 cps	10-14 cps

*Preliminary **at constant frequency

Figure 1: Spectra 256-Jet Printhead Specifications

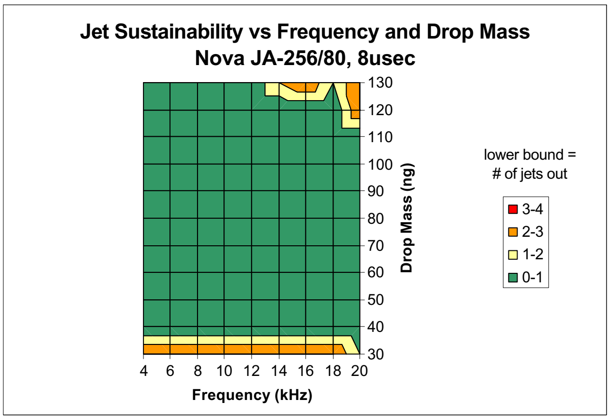

Figure 2: Spectra Nova Jetting Sustainability Plot

Materials Compatibility

Piezo technology offers significant advantages over CIJ and thermal ink jets in its ability to jet higher viscosity fluids, in excess of 20 cps in some cases. In addition, industrial piezo printheads are compatible with a wider variety of fluids than ever. Oil and solvent-based inks have been around for some time. UV curable inks have been demonstrated with piezo printheads recently and will be increasingly important as digital wide format printing seeks to penetrate the conventional screen printing market. Further, printhead design advances like physically isolating the PZT from contact with the jetting fluid extend piezo technology into the high performance water-based formulations that are promising not only in wide format, but also textile and wall covering applications.

Life

Wide format printers built to meet the demands of high dutycycle industrial printing require printheads with an equally robust construction. With an expectation that they will last years in service, the ink thrown by the latest generation piezo printheads is measured in 100's of liters. As an example of the qualification process for the VUTEk 2360™ printer, the Spectra Nova 256/80 printhead went through to 10 billion firing cycles, jetted 200 liters of ink, and was subjected to 1000 thermal cycles up to 125°C – and then measured to ensure that there was no significant drop in performance. Passing tests like these give printhead and printer equipment manufacturers alike the confidence that a printhead design is ready to meet the rigors of the industrial printing environment.

There are other features that will make piezo printheads more suitable for future industrial printing applications. One that has already been implemented is the presence of flow through passages in the printhead. This feature facilitates rapid color changeover in spot color scenarios and can also be used to circulate inks with heavy pigment loading. An erosion resistant metal orifice plate is attractive for jetting inorganic metallic pigments, such as TiO_2 for an opaque white ink or for colorants used in producing ceramic tiles. Further directions in piezo printhead technology include a broader range of available drop sizes, higher density jetting modules, and package form factors that are more easily integrated into larger printhead structures.

Recent Printer Developments

The most dramatic developments in industrial wide format printers have been in the evolution of the print engines. Largely limited to roll-to-roll offerings in the past, flat bed printer architectures have become more and more common. Now the latest generation wide format printers, like the VUTEk PressVu™, feature both flexible and rigid substrate print capabilities, as seen in the specifications shown in Figure 3. Now a single printer design can accommodate the range of substrates for most wide format printing applications. These new printer architectures position the printheads in a down-firing orientation to minimize the handling requirements of rigid substrates (ironically at a time when industrial piezo printheads have been designed to operate in a wider variety of orientations than ever before). The second most evident change has been the increase in the number of printhead nozzles, with numbers between 500 to 1000 per color becoming increasingly the standard.

These large numbers of jets, combined with the increase in printhead operating frequencies, has pushed the total printer productivity into the 80 to 100m^2/hour range for high quality graphics. A final architectural advance has been in the number of colors available, going beyond the typical 4 process color set to 6 and even 8 color systems.

Speeds: Ultra mode: Enhanced mode: Normal mode:	 500 sq. ft/hr (45.6 sq. m/hr) 800 sq. ft/hr (74 sq. m/h) 1000 sq. ft/hr (93 sq. m/hr)
Media:	Sheet or continuous feed, up to 72 inches wide Flexible or rigid substrates
Resolution:	360 dpi
Features:	Double strike capability for backlit signage. Inverted imaging for back-side printing
PressVu RIP:	- Multi-language graphical user interface - ICC color management - Tiling feature to simplify complex printing jobs - All popular desktop file formats, including Postscript®3, EPS, TIFF, and RGB
Inks:	VUTEk supplies solvent-based ink in four 3.75 liter bottles in cyan, magenta, yellow and black.

Figure 3: VUTEk PressVu ™ Specifications

Not so dramatic, but certainly as important, have been the non-architectural advances. In general the overall construction has improved in terms of robustness and ease of use by using machine components standard in the industrial machinery fields. Over the years, printer manufacturers have developed expertise in handling substrates precisely, and as print resolutions have increased, sub-pixel positioning requirements have become tighter as well. Coincident with the increase in the number of printheads has been the need to implement the means to replace and precisely align the nozzles quickly and easily. More nozzles and higher print frequencies translate into high data rates as well. Machines in the market today require in excess of 5Mbytes/second. This number will like double in the near future as higher productivity and higher resolution printers are introduced. However, the gross data rate does not tell the whole story. Wide format printer manufacturers have become masters at employing different interlacing and print strategies to satisfy the tradeoff between image quality and productivity on a job-by-job basis. Hence the data path must be capable not only of handling large data flows but be extremely flexible as well.

An emerging requirement for high productivity wide format printing has been in workflow management. The latest generation machines represent a significant investment in capital equipment. Good scheduling ensures that the high production capacity can be exploited to pay off this investment. Increasingly wide format printer manufacturers are bundling these tools with their equipment, like the VUTEk PressVu™ Production Control Station, shown in Figure 4.

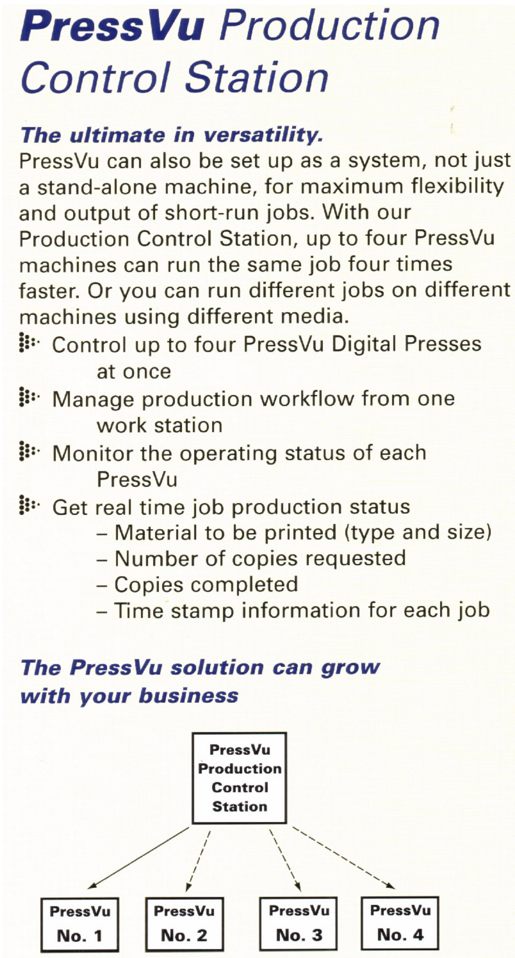

Figure 4: PressVu ™ Production Control Station

No other aspect of wide format development to date has validated piezo ink jet's role in industrial printing applications than the recent advances in reliability. These improvements, as evidenced by reduced printer downtime, less scrap produced, and lower maintenance costs, have been brought about by the combined efforts of ink suppliers, printhead developers, and printer manufacturers. These achievements have occurred against a backdrop of quicker drying inks (needed to support greater laydown rates), higher printhead jetting frequencies, and a drive to reduce the number of printer parts (in order to improve manufacturability). Printhead periodic maintenance requirements such as purging and wiping have been reduced as well, making more cycle time available for productive printing.

The increase in reliability is but one of many advances that have been brought about by an unprecedented level of cooperation between printhead manufacturers, ink developers, and system integrators. Printhead manufacturers have worked closely to help ink formulators understand the desired properties of jettable fluids and have provided printhead test equipment for the ink developers' labs. Printer manufacturers have collaborated with the ink providers to better understand ink/substrate interactions, drying/curing recipes, surface treatment requirements, and ink delivery methods. This cooperative approach has proven to be quite effective in the latest deployment of wide format printers and forms a template for future piezo technology expansion into other industrial printing applications.

New Market Paradigm

The upshot of these joint achievements by the equipment manufacturers and consumables suppliers is that the relationship between the market requirements and the technological capabilities has been turned on its head. In this new paradigm, the emphasis is on the end-user printing objectives and not the limitations of the digital technology. Printer specifications begin with the characteristics of the final printed product, then work backward to the substrate type, ink properties, and image quality targets before concluding with the printer architectural requirements and the selection of an appropriate printhead technology. This change in focus accelerates the rate of development of new platforms, not only in the wide format field, but for other applications which leverage off the same industrial digital printing technology. A case in point is VUTEk's introduction over a 16-month period of 4 distinct printer models:

Printer Model	**Print Width**	**Architecture**	**Application**
VUTEK 2360	2m	Roll-to-roll	Wide Format
VUTEk 3360	3m	Roll-to-roll	Wide Format
VUTEk PressVU	1.8m	Rigid and Flexible	Wide Format
DuPont 3210	3m	Roll-to-roll	Direct Textile

Here an adaptable printhead technology, coupled with a versatile print engine, facilitated the quick deployment of these diverse printer models.

Future Directions

This trend promises to further expand digital printing capabilities in the wide format arena in terms of increased productivity, resolution, substrate varieties, and ink families, with deeper penetration of the screen printing market as the ultimate goal. However, the same technical capabilities that have proved successful in wide format are equally attractive to other industrial printing fields. Direct printing of textiles in an example where the state-of-the-art in wide format has only just begun to hit the lowest productivity requirements of production printing. The introduction of water compatible industrial printheads has removed the last barrier to using wide format printing techniques to produce bedding, home furnishings, office partitions, flags, etc. Other applications hinge on the development of completely new types of jettable fluids. One example is the requirement for stable suspensions of heavy, inorganic metallic pigments for ceramic tile production. Electronic component fabrication could benefit from a variety of ink jet approaches, including laying down conductive traces, printing solder masks and component legends, and jetting long chain polymers. Advances in these chemistries and ink formulations, coupled with the bag of tricks developed over the years by the wide format printer manufacturers, will lead to the successful introduction of piezo technology to industrial printing for these emerging applications.

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Biography

Marc K. Torrey holds a Bachelors of Science degree in Mechanical Engineering from Rensselaer Polytechnic Institute in Troy, NY and a Masters degree from Lesley College in Cambridge, MA. He is a former employee of NASA and Boeing and has a strong background in real-time embedded control systems. Marc has worked for Spectra for over 15 years with piezo ink jet printheads, acquiring extensive experience in printhead design and prototype fabrication, system integration, and engineering consulting for a broad range of high performance industrial printing applications. Marc has recently moved to The Netherlands where he manages Spectra's sales and technical support activities in Europe and the Middle East.

Joseph A. Lahut graduated with a Bachelor of Science in Electrical Engineering from Northeastern University. He spent 8 years at the General Electric Corporate Research and Development Center in Schenectady, NY and 7 years at the GE Printer Product Department, in Waynesboro, VA, in development and product design positions. Mr. Lahut subsequently spent 10 years with Dataproducts Corp, primarily as Director of Ink Jet Technology. He has worked with VUTEk, Inc. for 5 years as Engineering Director, concentrating on application of ink jet technology, in the design of 1.8 to 5 meter wide, grand format, printer products.