Recent and Emerging Industrial Applications Using Ink Jet Technologies

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Abstract

The Digital printing revolution continues to take ink jet technologies into new industrial printing markets. The new products and concept printing systems recently introduced over the past couple of years, especially at DRUPA 2000 and other recent industry trade shows, exemplify this point as well as the convergence with conventional print applications. The digital market is seeing the emergence of new innovative ink applications, which are traditionally supported by conventional ink manufacturers, like Flint Ink. An example of this is the use of UV curable ink jet inks. The reason for the development of newly innovative inks is that end users are demanding to be able to print on more difficult substrates such as chrome and UV coated paper stocks, vinyls, polycarbonates, polypropylenes, polyethylenes, and glass. These new requirements are also making it more challenging since most of the substrates do not have an ink jet receptive coating on its surface. This makes the ink formulator's job more challenging. This paper discusses some of the recent and emerging industrial applications utilizing ink jet printing technologies, target substrates, and types of inks suitable for each application.

Introduction

Digital printing is a very familiar "buzz word" in the world of print today. Everyone has their eyes on which digital printing technology will come to the forefront and surpass all the other competitive technologies. The following digital technologies are used today[1]:

- Dielectric and Electrostatic
- Dry and Liquid Electrophotography
- Thermal Transfer
- Ion-Deposition
- Magnetography
- Electrophoresis
- Electro-Coagulation
- Ring Electrode Plates and Drums
- Office, Solid, and Industrial Ink Jet (Thermal, CIJ, and Piezo)

This paper focuses specifically on industrial ink jet applications and how ink jet is finding many niche market uses and how it is converging on conventional, or traditional, print markets. Continuous ink jet printing still dominates substantially in the packaging and direct mail/addressing markets. These technologies, from companies such as Marconi, Domino, Scitex, Imaje, and several other new players, are very fast and able to be easily integrated in a bindery line and/or an in-line packaging plant. At DRUPA 2000, Scitex Digital Printing also introduced the VersaMark Business Color Press ™ capable of printing duplex at up to 600 dpi resolution. Piezo drop-on-demand (DOD) will be the technology focused on in this paper.

Piezo DOD Technology Overview

It is very clear, however, that with the recent advancements in piezo drop-on-demand printheads, the future of industrial ink jet printing is at an evolutionary stage. Piezo drop-on-demand ink jet printhead technologies are considerably less expensive than its continuous ink jet counterparts. The diversity of ink technologies that can be used in piezo drop-on-demand printheads also makes the technology very intriguing. Continuous ink jets are typically limited to only one or two ink types (water and/or solvent). Thermal drop-on-demand ink jet is even more limited to water-based inks. Also, from an ink formulator's standpoint, piezo DOD offers considerably more formulation flexibility from both a physical chemistry (e.g., viscosity and surface tension) as well as a general formulation point of view. Piezo DOD inks can be from 2X to 20X times more viscous than either continuous or thermal DOD ink jet, which allows the formulator to use conventional ink resins and polymers. Most industrial piezo DOD printhead devices, such as Spectra, Xerox, Hitachi Koki, Xaar, Aprion, Trident, PicoJet, and IJT are capable of running the following types of ink systems:

- Solvent
- UV
- Oil-based
- Hotmelt (Phase Change)

Some of the printhead OEMs, such as Hitachi Koki, Aprion, PicoJet, and now Spectra are capable of running water-based ink jet inks. Spectra and Flint Ink recently announced the availability of the new water compatible printhead using Flint Ink water-based ink jet inks. This announcement was made by Spectra (www.spectra-inc.com) on January 9, 2001. Xaar, too, is expected to introduce a new water-compatible printhead sometime in the future.

It is important to mention that Epson technology has made a transition into grand format printing with an alliance with Rastergraphics. This will be discussed later. From an ink and printhead standpoint, Epson inks are typically water-based and are considerably lower in viscosity than the industrial

Traditional Print Markets

The worldwide value of print for traditional print markets has reached an estimated value of $800 billion,[2] based on I.T. Strategies analysis of the printing industry. Digital printing is now encroaching on traditional print markets. The table below depicts the total market size and how large of a potential opportunity there is for industrial digital printing. It will still take years for the current technologies, both printhead and inks, to completely replace conventional printing methods.

Table 1. Traditional Print Markets by Print Sales

Print Sales Range (in $Millions)	Print Markets (in $Millions)
$20 to $600	Trading Stamps ($22) Credit & ID Cards ($195) Coupons ($587)
> $600 to $1,750	Auto Carpet ($765) Auto Glass ($1,200) Transit Advert. ($1,530)
>$1,750 to $5,100	Metal ($1,887) Ceramics ($3,825) Display Advert. ($3,825) Fleet Decals ($5,100)
>$5,100 to $12,000	Multiwall Sack ($5,610) Posters ($8,920) Metal Cans ($9,945) Newspapers ($11,475)
>$12,000 to $20,000	Direct Mail ($13,260) Magazines ($14,790) P-Sens. Decals ($15,300) Labels ($19,125)
>$20,000 to $90,000	Wallpaper ($20,859) Folding Cartons ($21,165) POP Signage ($22,950) Flexible Pkg. ($65,790) Rigid Pkg. ($89,250)

With the advancements in piezo DOD ink jet printheads and inks, a lot of the traditional print markets are becoming more fit-for-use by such technologies.

A further look into some of the recent and emerging industrial applications utilizing piezo drop-on-demand technologies are discussed. The following specific applications are covered:

- Wallcoverings
- Direct Mail/Addressing
- Automotive (Robotic) Ink Jet of Windows
- Other Recent and Emerging Industrial Applications

Market Applications

Wallcoverings

Traditional Printing of Wallcovering

The wallcoverings market worldwide, based on the market data provided in Table 1, is about $21 billion. I.T. Strategies put together a comprehensive market analysis on Digital Color Printing of Wallcoverings (August 2000). In the US alone, the estimated size of the wallcoverings industry was about $1.1 billion to $1.6 billion in 1999.[3] The market can be divided into several categories arranged by sheet size:

- Commercial (about 54 inches wide)
- Murals (48 inches to 54 inches wide)
- Side walls (20 inches to 27 inches wide)
- Borders (10 inches to 12 inches wide)

The three primary analog printing technologies used for printing wallcoverings today are as follows:

- Flexography
- Gravure
- Screen

The inks used in each of the analog printing processes are as follows:

Table 2. Wallcoverings: Analog Processes and Inks

Analog Process	Ink Type(s)
Flexography	Water-based Alcohol-based UV Inks Other solvents
Gravure	Toluene and other volatile solvents
Screen	Oil-based UV Inks

The following current commercial substrates are used in wallcoverings and must meet the Federal guidelines dictated by Federal Specifications CCC-W408. The guidelines focus on requirements for flammability, tear strength, abrasion resistance, washability, scrubability, and stain resistance.

The substrates are as follows:

- Vinyl Coated Paper
- Paper-Backed Vinyl
- Fabric-Backed Vinyl
- String Effects
- Natural Textile
- Polyolefin/Synthetic Textile
- Acoustical Wallcoverings
- Cork and Cork Veneer
- Wood Veneer
- Underliners

The top traditional wallcoverings companies are as follows:

- Imperial Home Decor Group (Cleveland, OH)
- F. Schumacher & Co. (New York, NY)
- Rosedale Decorative Products (Concord, ON, Canada
- Omnova Solutions (Fairlawn, OH)

Digital Printing of Wallcoverings

It is very clear with the recent product announcements by several digital printer OEMs that the wallcoverings industry will undergo a revolutionary change. Digital printing provides the following major benefits:

- Significant reduction of very high inventory costs
- Ability to test designs to see which ones work without having to build inventory
- Customization that enables both commercial and residential users to design wallcovering to enhance their space, environment and even attitude.

In other words, digital printing is simple to use for short production runs, provides quick turnaround time, and offers custom printing. In the wallcoverings industry there is increased proliferation of patterns, and decorative borders in short runs lengths.[4] Today, approximately 80 percent of purchased wallpaper come from just 20 percent of the designs in inventory. The systems used to print wallcoverings are capable of immediate production with no tooling costs. A typical wallpaper print run can cost up to $5,000 on the rotogravure machines. Simply to engrave a cylinder with a six-color pattern can cost up to $1,200. And changing cylinders takes time.

In terms of price, digital printing fits into the high end of both commercial and residential wallcoverings markets. Traditionally printed wallcoverings can range in price from $1 per square foot to $20 per square foot, while digital printed wallcoverings can be made for $5 to $10 per square foot.[5] However, even though digital images place the product into the upper end of the price spectrum, flexibility of design and the opportunity to produce a unique installation make up for the additional cost. For example, a corporation or hotel can incorporate its logo into a wallcovering design. In residential settings, one-of-a-kind designs can add flare to a room.

The companies driving the move into digital wallcoverings can be divided into two groups: print providers and printer OEMs/Manufacturers. Print providers focus on digital printing of wallcoverings to end users, interior designers, and architects. The printer OEMs/Manufacturers focus on the development of unique printer systems to enable to creation of large-scale short production run wallcoverings output. One can research on the Internet for possible print service providers. One possible organization is Wallternatives. Wallternatives is a group of digital printers brought together by Rexam to promote the use of digitally printed wallcoverings. The key printer OEMs/Manufacturers providing large-scale digital printing systems for the wallcoverings markets and using piezo DOD printhead technology are as follows:

- Barco [Gent, Belgium]
- Digital Printing Systems [New York, NY]

Both Barco and Digital Printing Systems (DPS) introduced new products at DRUPA 2000 last year. The products as follows:

- Barco's the.factory[6]
- DPS' DPS65[7]

Table 3. The.Factory and DPS65 Printer Systems

Printer	the.factory	DPS65
OEM	Barco	DPS
Technology	Xaarjet 500	Aprion
Resolution	360 dpi (grayscale)	600 dpi
Substrates	Vinyls and others	Vinyls and others
Ink Type	UV Curable	Water-based
Press Type	Roll-to-Roll	Roll-to-Roll
Max. Print Speed (sq.m/hr)	Up to 800 sq.m./hour	Up to 185 sq.m./hour
Print Width	14 cm to 63 cm	Up to 165 cm
Pre-treatment	Corona	Heat
Post-treat	UV Curing	Heat

As can be seen, both companies have taken very different ink technology approaches in addition to selecting different printhead technologies. The wallcoverings industry will need to keep an eye on how successful these two industrial printing systems, and other printers that will inevitably evolve, on their markets.

Direct Mail/Addressing

The direct mail market size, as indicated in Table 1, is about a $13.3 billion market for traditional print worldwide. Digital printing is not new to this market application. The direct mail/addressing market sector has long been dominated by continuous ink jet systems, such as Scitex, Marconi (Videojet), and Domino. Trident used to also be a dominant player in the direct mail/addressing market. Trident's printhead technology is based on piezo DOD. Trident's technology, although still used in this market sector today, is not demonstrated at such trade shows as the National Postal Forum or Mailcom.

Hewlett Packard's SPS Division has made a major impact, very quickly, in this market. There are now 10 or more companies utilizing HP's thermal ink jet technology for direct mail/addressing systems. One such company is Buskro Ltd. (Pickering, ON, Canada). The ink systems are being made available in both single 42mL HP51645A cartridges and 420mL bulk ink delivery systems. The HP51645A print cartridge is

capable of printing up to 600 dpi, with a majority of companies printing at 300 dpi. HP presented a paper at the IS&T's NIP15 International Conference on Digital Printing Technologies titled Application of Thermal Ink Jet Printing to Industrial Markets.[8] This paper gets into HP's approach, from a technical marketing standpoint, and can provide more insight to the reader interested in reading further. The main key benefit thermal ink jet has over its competitors is initial cost of ownership and flexibility of "snapping in" a cartridge or two and start printing. Another printing system, utilizing HP thermal ink jet technology, was also introduced at XPLOR 2000 by Kerning Data Systems.[9] It incorporates 30 HP printheads and can run up to 250 feet per minute at 600 x 300 dpi. It can run at 125 feet per minute at 600 x 600 dpi.

Buskro Ltd., as mentioned earlier, offers their customers an HP printer system called the Buskro HPQ Inkjet system. A new product introduced to the market a couple of years ago, called the Buskro Elite, utilizes piezo DOD technology and hot melt inks. This printer system has done very well in Europe. The use of hot melt inks, however, has proven to create an abrasion issue due to the mail handling systems in the U.S. In order to address this issue, Buskro has developed a new printer system called Atlas using Monet inks, which was technology demonstrated at GraphExpo in Chicago, IL in September 2000. This is a higher resolution, faster ink drying system than the previously offered Trident solution Buskro once sold. The new printer system will be capable of printing over 25,000 mail pieces on more difficult coated card stocks. This includes chrome coated, UV coated, and other various types of direct mail pieces. These new printer systems are able to print at upwards of 100 ips at 300 dpi. This is at a printhead operating frequency of about 32 KHz.[10] An important correlation is the relationship with print resolution and actual print speed and production count (PPH). The following table depicts the relationship for the Buskro's Elite printer system:

Table 4. Buskro Elite @ 22KHz

Resolution (DPI)	Surface Speed* (in/sec)	Count* (PPH)
300	73 ips	23,900
400	55 ips	18,000
600	37 ips	12,100

*The production counts per hour (PPH) is based on a No. 10 envelope having a 9" length and a 1.5" inter-piece gap for a total of 11". Hence for longer pieces the production rating should be decreased, and conversely for a shorter piece, the rating should be increased.

Ink pricing sensitivity for the direct mail/addressing market is based on a "cost-per-1000-piece" mail basis. Historically, Scitex CIJ inks typically cost about $0.08 to $0.12/1000 pieces. Videojet and Domino type CIJ inks typically cost about $0.20 to $0.35/1000 pieces. The following table highlights the typical price range for the piezo DOD ink technologies used in the market today:

Table 5. Industrial Ink Jet Direct Mail/Addressing Cost per 1000 Print Range for Various Technologies

Technology	Resolution (DPI)	Cost (US$) (1)
Trident (2)	150*	$0.21 to $0.35
HP (3)	150	$0.28 to $0.78
HP (3)	300	$0.60 to $1.56
HP (3)	600	$0.89 to $2.32
Elite (4)	300	$0.69 to $0.79
Elite (4)	600	$1.38 to $1.58
Monet (5)	300	$0.22 to $0.25
Monet (5)	600	$0.44 to $0.50

* Only offered @ 150 dpi.

(1) Cost per 1000 pieces is based on a 6-line address containing on average 100 characters using an Arial 11 point font. The values are based on empirical studies, and where not obtainable, on the manufacturer's specifications. Buskro Ltd. as the preferred manufacturer.
(2) Trident: based on a 125 mL bottle of AllWrite ink @ approx. $50 USD.
(3) HP: based on ink pricing for bulk ink from Collins @ $150 USD/420 mL to $39 USD/single 42 mL ink cartridge
(4) Elite: based on a 100 gram hot melt ink block @ $55 USD/block
(5) Monet: based on a 1 liter ink container of Monet ink @ approx. $400 USD.

The table above clearly indicates the challenges that the HP printer systems have on controlling consumable costs compared to the new competitive industrial piezo systems emerging on the market today. The following table highlights some of the other competitive differences between an industrial piezo DOD system to that of a thermal ink jet system:

Table 6. Piezo DOD vs. Thermal Ink Jet Systems

Attributes	Piezo DOD (Atlas)	Thermal Ink Jet (HPQ)
Ink Supply	1 liter or more	42 mL or 420 mL
Ink Dry Times	Very fast on more difficult substrates	Slower than DOD inks
System Costs*	More expensive than Thermal IJ System	Less than Piezo DOD System

*Contact Buskro For More Information.

Although HP has taken root in the industry, it does not address all of the concerns facing the end users today, especially high volume ones. Hence, the introduction of Buskro's Atlas printer system. The new printer has the following major attributes:

- Quicker ink dry times
- Lower cost per 1000
- Improved system reliability and robustness

The new Atlas printer/Monet ink system was developed in collaboration with Buskro, Flint Ink, and Spectra.

Automotive (Robotic) Ink Jet of Windows

Ink jet printing of automotive windows is a brand new field that is being pioneered by ExatecTM LLC (www.exatecglazing.com). Automotive windows, as indicated in Table 1, are about a $1.2 billion industry. In 1998, Bayer and General Electric formed ExatecTM as a 50:50 joint venture for developing and supplying polycarbonate glazing for automotive windows. In 1999, a facility was built with integrated manufacturing operations in Detroit, Michigan to serve as a global center for window systems development and demonstration. This center, operational since early 2000, is designed to deliver small-scale production quantities of windows for engineering validation. Exatec's European office is based outside of Cologne, Germany for market, design, and engineering development for the strong European market.

Polycarbonate glazing has the following major advantages to the automotive industry:

- Weight Reduction of up to 50% (better fuel economy)
- Design Innovation and Styling Freedom (highly curved and complex shapes, colors and molded-in features)
- Advanced Coating Technologies (Unique multi-functional coating layers, glass like abrasion resistance, and inherent UV/IR screen)
- Engineering Performance (Better noise performance, optics designed to closely match glass)
- Safety and Security (Occupant retention, reduces smash and grab theft, superior toughness to glass, minimizes potential for breakage)
- 100% Recyclable Materials (both the polycarbonate and the coating system)

Exatec™ approached Flint Ink's Digital Division to work with them to provide an ink jet ink solution for their polycarbonate glazing operation utilizing ink jet technology. The print provides the blackout decoration that protects the adhesive used to mount the windows onto the automobiles. After carefully selecting which printhead Exatec™ would use, a Spectra CCP-256 printhead, the final ink system was developed. An unique solvent-based ink that has been optimized to be compatible with Exatec's primer and topcoat systems was developed. The uniqueness of the whole system, which is new to industrial ink jet, is the incorporation of a highly sophisticated paint robot.

The following diagram illustrates the key elements of the system:[11]

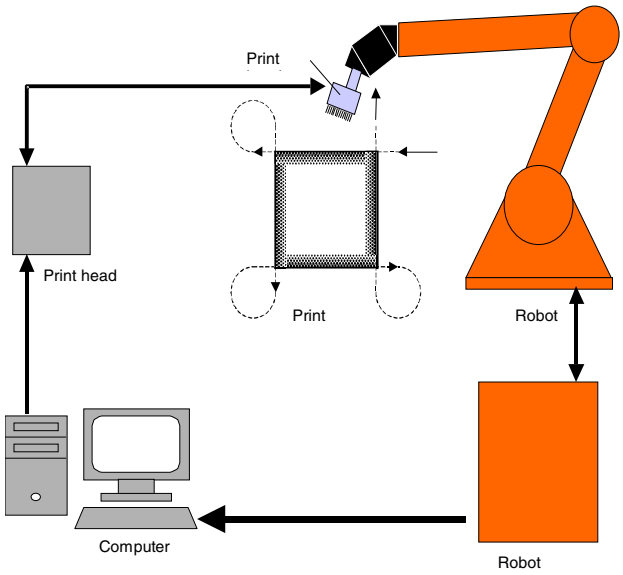

Figure 1. Exatec™ Robotic Ink Jet System Diagram

ExatecTM has the following patent protecting this technology:

- Process for Providing Decorative Imprinting on a Molded Plastic Automotive Window Panel, WO0078520, van der Meulen Eric FJM; Matsco Mark M; Katsamberis Dimitris, Exatec LLC (US).

This patent mentions specifically an ink jet process using a robot manipulator. Several additional patents are in the process of being approved.

The feasibility of the system was demonstrated in 2000. With several patents protecting the technology in place, Exatec™ should be providing engineering samples for customer demonstration during 2001.

Other Recent and Emerging Industrial Applications

The past couple of years have highlighted several additional major breakthroughs in the industrial use of piezo DOD ink jet technology. These major breakthroughs are in the following areas:

- Industrial Packaging
- Ceramic Decoration
- Hybrid Conventional/Digital Presses
- High Speed Label Printing Systems

Philip Morris Research, Development and Engineering discussed the current status and shared a road map for success in the area of digital printing in industrial packaging applications.[12] In the article presented at the NIP16 in Vancouver, B.C., Canada last October, they specifically mention that piezo DOD has matured to the point where it is now becoming a preferred technology for high quality and high resolution

printing systems. The folding carton packaging market alone is about a $8.3 billion industry alone. The flexible and rigid packaging markets are considerably larger, as indicated in Table 1 at $65.8 billion and $89.3 billion respectively. Water, solvent, and UV curable ink jet inks will all be needed for this very large market sector.

Xaar Technology Ltd. and Ferro Enamel have actually designed and commercialized a digital printing system for ceramic decoration.[13] A joint paper was presented at NIP16 in Vancouver, B.C., Canada last October. This is a real niche market application. However, the worldwide print value onto ceramics is about $3.83 billion, as indicated in Table 1. The current system is using UV curable ink jet inks. The initial development started in December of 1998.

A new technology concept system, featuring a hybrid conventional/digital press was introduced at DRUPA 2000 last May by Heidelberg and Spectra.[14] The printhead is a 325mm wide piezo DOD printhead attached to an offset press. The print resolution is 600 x 600 dpi and a print speed of up to 10,000 DIN A3 sheets per hour. The printhead has over 7500 individual nozzles and jets at upwards of 38 KHz continuously. The printing system showed utilized UV curable, pigmented ink jet inks. This market sector, commercial and publication printing is huge.

Chromas, Spectra, and the Digital Label Alliance showed the Argio 75 SS at DRUPA 2000 also.[15] The printer system was integrated with a Didde Web Press. This represents a solution for the $19.1 billion label market. The printer system can print up to 100 ft/min, uses UV curable inks, which enables printing on a variety of coated papers, films, foils, and board. The printhead is 7.5 inches.

Conclusions

It is very clear that the digital printing industry is undergoing an "industrial revolution". The wallcoverings, direct mail/addressing, automotive windows, packaging, ceramics, labels, and commercial and publication printing markets are already undergoing the digital revolution. There are many new ink and printhead technologies that are evolving and will continue to encroach on traditional print. Printheads are becoming more compatible with a multitude of ink chemistries. Piezo DOD printheads are also becoming available in both wider and faster varieties. As this technology continues to evolve, more and more traditional print applications will be replaced.

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Biography

Nathaniel R. Schwartz is the New Technology Manager for Flint Ink's Digital Division at the Ann Arbor World Headquarters location. He has over 10 years of ink jet experience. At Flint Ink, he is responsible for new business development for Flint's piezo drop-on-demand ink jet development efforts. He has co-authored several papers and holds 2 U.S. and European patents. He received his B.S. (1990) and M.S. (1998) in Chemical Engineering from the University of Massachusetts Lowell and is an active member of IS&T.