UV Inkjet Label Printing

Getting it Right on the Customer's Substrate

By Josh Samuel and Jennifer Renner

Drop-on-demand inkjet printing, familiar to most of us from small home and office printers, is taking an increasing role in printing for the broader commercial and industrial market. Inkjet printing has made serious inroads into the market for printing banners and signs of all sorts. Wide-format and super wide-format printing is now the norm and has, to an increasing degree, superseded analog printing as the method of choice for printing large format and point-of-purchase signage. Overall, inkjet printing has now taken over 30 percent[1] of the general sign and banner market.

One area of printing that holds promise for future growth is that of packaging and labels. Many forms of commercial printing, although a huge market today, are threatened on multiple fronts from various forms of electronic media. Printing and decoration for packaging, on the other hand, is expected to increase in volume in the foreseeable future. In spite of this great promise, penetration of digital printing, in general, and inkjet printing, in particular, into packaging and label printing is still in the low single digits.

This article will focus on the label market as an example of printing for packaging. Printing for packaging is a much broader and diverse subject than just labels, but many of the conclusions that follow can be extrapolated to the broader packaging market.

Toner-based methods, both wet and dry, have been at the vanguard of penetrating the label market. Today, inkjet is slowly gaining market share. Inkjet has great potential because there is more flexibility in the type and characteristics of fluids that can be applied from an inkjet head.

While there are many possible explanations for the relatively low penetration of digital printing into this market, this article will concentrate on the technical challenges involved in reliably printing labels of acceptable quality with inkjet printing. Only now is the inkjet printing industry overcoming these challenges.

Challenges

There are challenges in inkjet label printing, but there are ways UV-curable ink can help meet them. In trying to understand the challenges of label printing with inkjet, it is instructive to consider the different requirements for printing labels versus printing using a wide-format process.

Figure 1

Example of a wide format printer

The print heads and lamps are mounted on a carriage that shuttles back and forth over the substrate. The printer can operate in various modes—laying down drops at a resolution that depends on the number of passes.

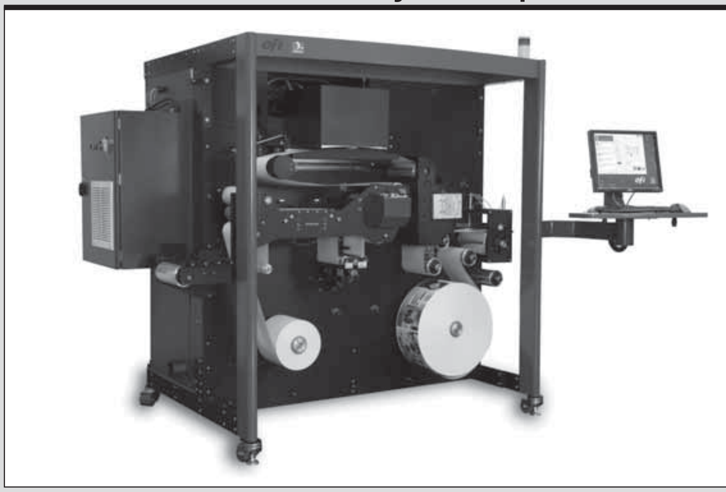
The main technical difference is that label production is a single-pass process where the substrate moves continuously from an unwind roller, is printed, and must be rewound fully dried or cured (possibly after converting) onto a rewind roll.

Wide-format prints a single area with a number of passes underneath print heads. A printed area will normally be produced by a plurality of nozzles. A common method is to shuttle the print heads back and forth over the substrate, advancing the substrate on demand and enabling various modes of printing. Multi-pass printing enables flexibility in how much ink is deposited and is forgiving as far as imperfections in drop placement and even to missing nozzles. An example of a wide-format printer can be seen in Figure 1.

For single-pass printing, there is only one opportunity to deposit drops and form the image. This imposes major requirements on single-pass printing. An example of an industrial inkjet label printer can be seen in Figure 2.

Figure 2

An EFI Jetrion industrial inkjet label printer



Requirements

- Drops need to be accurately deposited. Drops that are deposited at a slightly skewed angle will show up as a visible flaw.
- During printing, a missing nozzle will show up immediately as a flaw. Since label printing is a continuous process, this imposes a requirement of nozzle sustainability during runs that may extend over hours.
- Drying or curing of the image needs to happen efficiently in time and space so that the label may be converted (i.e., die cut, matrix stripped) and rewound.

Energy-curable formulations are particularly well-suited to meet these requirements. One of the great advantages of UV-curable inks is that it separates the ink solidification process after printing from the potential for drying in the nozzles. This enables quick curing after printing but enables good reliability of the print head.

An additional advantage of UV-curable inks is the durability that a properly formulated ink may show after curing. It has been possible to obtain Underwriters Laboratories® (UL) recognition for digitally printed UV-cured durable labels without additional coatings or laminates.

One less obvious advantage of inkjet printing of labels is that it is a very well-defined process where the ink is not accessible or subject to operator change as in many analog processes. Indeed, inkjet printing of UV-curable inks onto a specific substrate using a defined digital press has been recognized by UL as a reliable system. Once vendors have proven that an ink substrate combination passes durability tests, this combination may be used by additional printers using this ink, material and printer combination without the need for requalification.

Printing on a Multitude of Substrates

Digital printing of labels has many advantages over analog printing. In digital printing, as the print goes from concept to electronic file to substrate, there is no need for an intervening step of making some form of plate that will make the impression. This is becoming increasingly valuable as runs and turnaround times get shorter. In practice, digital printing can only move further into the market by displacing deeply entrenched analog printing methods.

When moving into an existing analog market with digital printing, the printer expects the new digital print method to be a drop-in for his customers. One major requirement is that the new method must be able to print well on the myriad of customer substrates that the existing print method currently prints well on.

There is a fundamental difference in how ink is applied in inkjet printing versus analog methods. Analog printing is a contact method where ink is applied to the surface by being pushed up against the substrate. Inkjet printing is a non-contact method where the deposited drops have to spread spontaneously and form the image. The wetting and flow requirements are very different. These differences make it challenging to print with sufficient quality on the same range of substrates used for analog printing. These challenges can be overcome by formulation, surface treatment, and judicious selection and testing of substrates.

In conventional printing, people commonly test the suitability of a substrate based on a dyne level test. This is a rough measure of the surface energy determined by observing the wetting of a set of mixed fluids with known surface tension. A commonly used rule of thumb is that if the substrate has a dyne level that is seven to 10 dynes·cm^{-1} higher than that of the ink, print quality and adhesion will be good. There is a common expectation of customers using a digital press that the same rule of thumb will hold true for this new method of printing. This turns out not to be the case. While a sufficiently higher surface energy of the substrate vis-à-vis the surface tension of the fluid is a minimal requirement, it does not guarantee good print quality and cannot be used as an efficient screening test.

Comparison of Dyne Levels and Print Quality

Experimental

Standard label stock, coated polyethylene terephthalate (PET), and bi-axially oriented polypropylene (BOPP) substrates from mainstream vendors were printed on the Jetrion 4830 digital label printer. Print speed was 70 feet/minute. Substrates were tested for dyne level using a fresh set of ACCU DYNE TEST™ marker pens purchased from Diversified Enterprises. The BOPP substrates were also printed after being corona treated in-line at a level of 0.3 or 0.8 kW. The spot size of individual drops was measured with a Keyence VH-X microscope at 300x magnification.

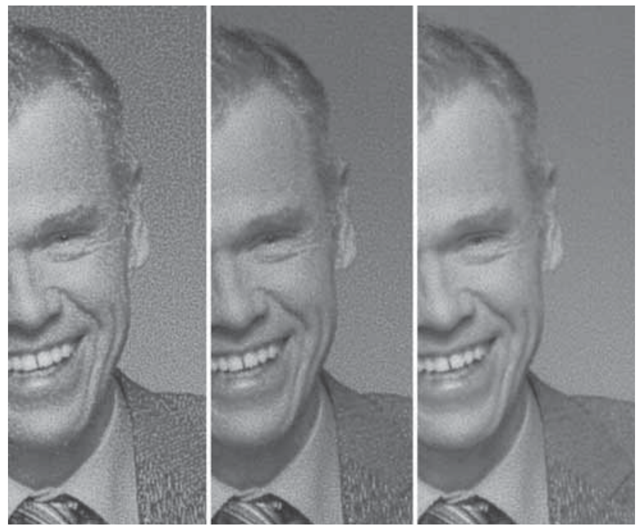
Results

In the prints we can see the same image printed on three materials—two coated BOPP materials from two different vendors. In addition we can see a coated PET material (Figure 3).

The surface energy as measured with the dyne pens is very similar for the three materials—BOPP#2 and PET measured as 34 to 36 dynes·cm^{-1}. BOPP#1 was measured as 36 dynes·cm^{-1}.

Figure 3

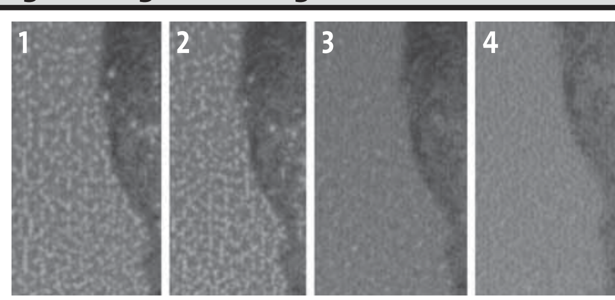
Images printed on Jetrion 4830 label press



BOPP#2 BOPP#1 PET

Figure 4

Enlarged images from Figure 3



BOPP#2 BOPP#2 BOPP#1 PET

For BOPP#2, jet lines are evident owing to insufficient spread. In-line 0.3 Watt corona treatment (shown in image 2) increases dyne level above 58 dynes·cm^{-1} but does not improve the image. In BOPP #1, spread is sufficient so that the residual flaws appear somewhat like pinholes. For PET, image quality is good.

Table 1

The increase in dyne level shrinks the dot diameter slightly

Substrates	BOPP#1	BOPP#2	BOPP#2 0.3 Watt Corona	PET
Dyne level (dynes·cm-1)*	36	34-36	58	34-36
Print Quality	marginal	poor	poor	good
Spot Diameter (micron)**	163±1	142±1.5	138±1.5	179±1.5

*Dyne level measured with pens as described in the text. ** Spot diameter of black ink of largest drop (45 ng.)

It is clear from the prints that the three materials do not exhibit the same image quality. The PET film exhibits acceptable print quality while BOPP#1 shows what we consider marginal print quality and BOPP#2 unacceptable print quality. The ink used in this case has a surface tension of 22 ±1 dynes·cm,$^{-1}$ so that the substrate is over 10 dynes·cm^{-1} higher in surface energy than the ink. Indeed, adding in-line corona treatment of either 0.3 kW or 0.8 kW, although it increases the dyne level above 58 dynes·cm^{-1}, it does not improve print quality (Figure 4, image 2). As can be seen in Table 1, the increase in dyne level actually shrinks the dot diameter slightly.

Discussion

The print quality is closely linked to the drop size and shape attained by the ink before it reaches the cure lamp. As can be seen in Table 1, the best print quality is obtained with the largest spot size. Although the simple test of the dyne level does give an indication of surface energy, it relates to the specific set of fluids that is being used in the pens. Surface energy is more complex and has been modeled in various ways. One of the commonly used methods splits the surface energy into polar and dispersive components. There are additional factors that affect the spread and quality, such as absorption of the ink into the upper layer of the substrate or solubility of the upper layer of the substrate in the ink. In addition, surface roughness of the substrate has a large effect on spread and the shape of the drop.

The method of executing the dyne test by applying a solution by contact is much closer in character to contact printing. The dyne level is measured by observing de-wetting of the solutions that is determined by the receding contact angle. The spread of the inkjet drops is determined by the advancing front of the fluid (the advancing contact angle). The receding contact angle on real surfaces is lower than the advancing contact angle.[2] Lower contact angle leads to better wetting. This means that a liquid may not spread well on a specific substrate (determined by the advancing contact angle) but will not retract when forcibly spread onto the surface. Both experimentally and theoretically the dyne test is not a suitable test to determine if a substrate will print well using an inkjet printer.

Summary

Inkjet printing is coming of age as a means of producing prime labels, not only for coding and marking as in the past. Previous dedicated trade shows such as Label-expo have shown an increasing number of suppliers offering inkjet label presses. We fully expect the number of presses available to increase. At this point, the majority of these presses use UV-curable inks. While UV inkjet cannot print on all substrates that the customer can use with an analog press, it is possible to print on many off-the-shelf materials from most common classes of standard label stock. This includes films such as PET, BOPP, vinyl, polyethylene and metalized films. We are also able to print on paper stock, including matte litho, semi-gloss and matte papers. Semi-gloss and cast-gloss papers are most challenging and often require additional primers.

Simple tests such as the dyne level test are not predictive of print quality. For substrates that are not in a tested library, the best way to determine if the substrate is suitable for UV inkjet printing is to actually print on it. ◗

Acknowledgements

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References

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—Josh Samuel is technology development manager and Jennifer Renner is senior manager with the Ink and Substrates at EFI-Ink Group in Ypsilanti, Mich. They can be reached at josh.samuel@efi.com *and* jennifer.renner@efi.com.