Overview of Industrial Digital Printing

William R. Dougherty and Ann Reitnauer
Markem Corporation
Keene, New Hampshire

Abstract

There are many different methods by which to apply marks and codes either directly on product packages (primary packaging) or in cartons or cases of that product (secondary packaging). The following is an overview of different types of digital printing technologies used for industrial marking applications. The paper will explain the use of piezo drop-on-demand (DOD) ink jet with both phase change and liquid inks. Other ink containing systems that will be reviewed include continuous ink jet, valve jet, and thermal transfer. In addition, one non-ink containing digital marking method – a laser printing system- will also be discussed. The end user's choice of digital printing technology is determined by the application requirements of the product being marked, including: the size and shape of the mark or code, print speed, adhesion requirements, substrate, environmental requirements, and cost per print. The benefits and disadvantages of each technology will be discussed in relationship to these requirements.

Introduction

Manufacturers of goods are placing marks and codes on their products for a variety of reasons. Examples of these are date codes that are used to identify freshness or "best if used by" dates. Lot numbers are used to note the date of manufacture and/or for traceability. Barcodes are used for tracking or for reading price information. Logos and symbology are used for advertising and to create brand recognition.

Industrial marking and coding comprises the imaging of alphanumeric characters, graphics, and barcodes on manufactured goods, and excludes office printing, web and wide format printing. The marking systems are exposed to industrial environments, and must be adaptable to a wide variety of packaging lines. For example, the systems must be capable of placing marks on a products that are presented in different orientations, such as horizontal flow film or vertical form fill and seal. Also the systems must be robust enough to take the impact of package collisions and still provide precise marks.

There are numerous examples of digital industrial marking applications on various substrates. Package date coding and lot numbering such as on food, beverages, and pharmaceutical packages is placed on film, paper, rigid plastic, metal, glass, and tagboard cartons. Cases or boxes of goods are often marked by case coders onto corrugate, wax coated corrugate, or shrink-wrap. Specialty label printing like fabric wash and care labels is usually done on coated fabric. In addition to package coding, marks are also placed directly on products such as cable, wire, fasteners, and Velcro®.

In order to discuss the different types of digital printing, it is useful to clearly define what digital printing means. First there is software in the system that works with the electronics to create and control the variable information printed or marked on the product. Typical examples are date codes, lot numbers and/or company logos. Second, generally, digital printing does not contain movable type or printing plates. Third, there is usually an automatic updating of information that will be printed. All of the methods are known for providing a flexible format to the end user for creating and changing product marks and codes quickly.

To be able to choose the appropriate digital marking system for a particular application, the end user must assess both the fixed and variable requirements. Examples of the fixed variables would be the mark or code size, and the type and placement of the characters that need to be printed. The substrate being marked is usually previously chosen by the manufacturer of the product. These factors will effect the choice of marking equipment since, for example, not all technologies are capable of printing barcodes, nor do they all print at the same speed. Some of the variable requirements depend on the particular application and sometimes it is difficult to get all of the desired properties without giving up something else. For example, the cost per print, cost of ownership and cost of maintenance; may be balanced against the print density and resolution of the code. While some end users require perfectly formed characters, others are satisfied with a code that is just readable. Similarly, some applications demand marks with excellent adhesion to the substrate, while in other areas this may not be as important.

Overall, as the end user prioritizes the fixed and variable requirements, then it becomes easier to match these with the unique benefits of a particular printing technology. This paper will describe the benefits and deficiencies of each printing technology and match these with particular application requirements.

Hot Melt Drop-On Demand (DOD) Ink Jet

A hot melt or phase change drop-on-demand (DOD) ink jet printer uses a bank of several nozzles, where the jetting mechanism fires a molten ink drop via a piezoelectric element. This technology uses elevated temperature to melt the ink, which is a solid at room temperature, and yield a low viscosity liquid. Drops are then jetted from the print head to form the mark or code. As the ink droplets hit the substrate, they adhere and freeze very rapidly. A photograph of a typical hot melt DOD code on a polymeric film substrate is shown in Figure 1.

Figure 1. Typical Hot Melt DOD Code

Figure 2. Hot Melt DOD Ink Jet Printer

The mark is actually 1/4 of an inch high on a candy bar wrapper. A picture of a hot melt DOD printer down-jetting onto a product on a production line is shown in Figure 2.

The key differentiations of hot melt DOD ink jet technology are that there is no volatile solvent in the ink, and the ink mark dries upon contact with the substrate. Also, since the inks are 100 percent solids, and very little waste is generated, the technology is less messy and very environmentally friendly. In addition, this technology can print at high speeds of up to 650 feet per minute, at high resolution, with the ability to print characters as small as 4-point type. These features make this technology very versatile. High speed packaging lines that require multiple lines of print, which may include alpha numeric, symbols, logos and barcodes can all be printed at various print densities that range from very light to very dark.

One of the disadvantages to hot melt DOD ink jet printing is that the adhesion of the inks is substrate dependent. Most inks are specialty hot melt adhesives that, due to their low viscosity requirements, are high in wax concentration. While this affords excellent adhesion to packaging films, paper, and porous materials, the inks do not stick very well to rigid plastic, metal or glass substrates. Also, the distance from the printhead to the substrate, or throw distance, usually must be no greater than 0.25 inches. For applications where the product is not presented as a flat surface, such as concave surfaces, it may be difficult to achieve the desired print quality and adhesion. The variable throw distances that the ink drops will have to travel from the printhead to a curved surface will result in the improper formation of characters and a blurred print. Also, if the drops travel farther than the maximum throw distance, they may cool too much, freeze, and not have good adhesion to the substrate.

Overall, hot melt DOD ink jet technology is highly recommended for marking packaging films, such as candy bar wrappers, and corrugated cardboard, such as that used in cardboard trays. Also, the high resolution allows for several lines of text, use of symbology and barcodes such as is seen on corrugated boxes. Lastly, the excellent adhesion of the inks to porous substrates fits this technology well to marking corrugated, Velcro® or Styrofoam.

Liquid DOD Ink Jet

Similar to the hot melt DOD ink jet, liquid DOD ink jet uses a bank of nozzles and the jetting mechanism fires a drop via a piezoelectric element. However, in this case a liquid ink is used to form the mark or code and the ink dries on the substrate by evaporation, absorption or curing. Figure 3 shows a fabric label printed with a liquid DOD ink jet printer. Figure 4 shows a Liquid DOD ink jet printing system that can produce the label shown in Figure 3.

One of the advantages of liquid DOD ink jet is that fast printing speeds of up to 650 feet per minute can be reached, depending on the dots per inch of the printhead. Also a high density, high resolution print can be achieved at slower speeds. There are a variety of inks, including slow-drying oil based inks; fast-drying solvent based inks for non-porous substrates, and curable inks for higher durability. Similar to the hot melt DOD ink jet technology, this technology is capable of marking on high speed packaging lines that require multiple lines of print which may include alpha numeric, symbols, logos and barcodes. These can all be printed at various print densities that range from very light to very dark.

The are some drawbacks to liquid DOD ink jet. If solvent-based inks are used, evaporation must occur before the ink mark is permanent, and some inks contain volatile organic compounds (VOC's) and/or hazardous components.

Figure 3. Fabric Label Printed with Liquid DOD Ink Jet. The code is 3/4" × 2".

Figure 4. Liquid DOD Ink Jet Printing System

Similar to hot melt DOD ink jet, the throw distance is limited to applications less than 0.25 inches. Lastly, working with liquid inks can be messy.

Due to the variety of inks available in liquid DOD ink jet, there are several applications where this technology works especially well. The oil-based inks perform well on porous substrates like corrugate and fabric label tape. Whereas the solvent borne inks work well on signage such as custom banners and billboards.

Continuous Ink Jet – CIJ

A CIJ printer ejects ink drops at a fixed rate from a single orifice at high pressure. The drops are charged and ejected continuously through two deflecting plates, which are also charged. In flight, the deflecting plates turn on or off causing the drops to move in flight to form characters on the printing surface. Non-deflected drops are jetted into a gutter and are re-circulated back into the system. CIJ uses liquid ink which is typically solvent based. If the ink is jetted onto a non-porous substrate, it dries by evaporation. However, if the ink is jetted onto a porous substrate, then the ink dries by a combination of evaporation and absorption.

Figure 5 shows a typical CIJ print on a primary pharmaceutical package. The code is actually about 1/4 inch high. Figure 6 shows a photo of a typical CIJ printing system.

Probably the biggest advantage of CIJ is the printing speed, which reaches up to 1000 feet per minute. As an example of how fast this is, there are applications where a CIJ printer can apply 24 codes per second to the bottom of beverage cans. Another advantage is that a variety of substrates including rigid plastics, metal, glass, and chipboard cartons can be marked with quick drying inks that have very good adhesion. In addition, the CIJ printers have a throw distance of up to 1 inch, which allows for marking on irregularly shaped objects. Lastly there are several different types of inks for CIJ including solvent based, water based, and UV curable inks, available from many sources.

The drawbacks of CIJ are that the print resolution is lower which limits its use to alphanumeric characters and makes printing readable barcodes or logos difficult. There is an environmental concern since many of the CIJ inks contain VOC's and/or hazardous flammable components. Also, drying time is limited by the evaporation rate of the solvent(s) used in the CIJ ink. For example, a water-ethanol-based ink may dry more slowly than a methyl ethyl ketone (MEK) or ethyl acetate based ink, and ultimately this may effect the achievable line speed. In addition, due to the continuous emission of ink from the printhead, the printers can be quite messy.

CIJ does very well in marking metal cans such as beverage cans. CIJ is also used to mark glass bottles, and rigid plastics, such as those used in beverage bottles and caps. Cereal boxes made from chipboard are also easily marked with CIJ printing systems.

Figure 5. CIJ Print On A Primary Pharmaceutical Package

Figure 6. CIJ Printing System

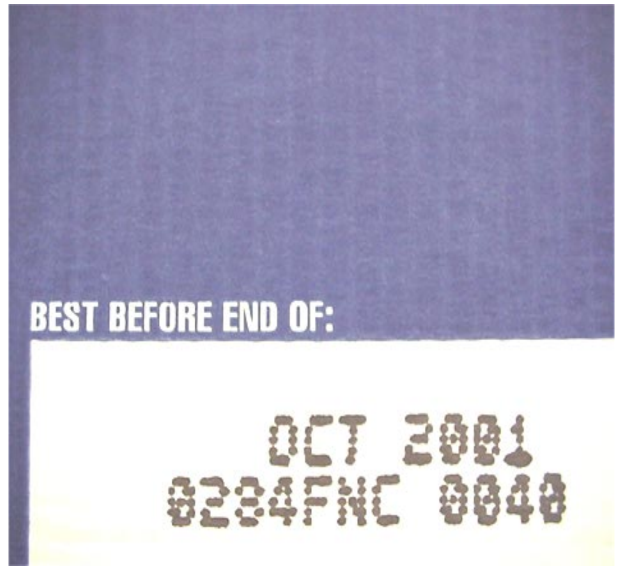

Figure 7. A code from a valve jet on a corrugated case.

Figure 8. Valve Jet Printing System

Valve Jet

Valve jet printers use a bank of nozzles that contains a jetting mechanism, which fires a drop from a pressurized ink supply, via a solenoid valve. Liquid, low viscosity inks that are water based are typically used to form the mark or code and the ink dries by a combination of absorption into the substrate, and evaporation. A 2-1/2 inch code from a valve jet is shown in Figure 7, and the printing system is shown in Figure 8.

The advantage of valve jet is strong print opacity. This allows for large characters that can be read from far away distances, for example, a forklift operator reading a case in a warehouse. Also, since most of the inks are water borne, this technology is regarded as being very environmentally friendly. Good adhesion on porous substrates can be attained due to the ink absorbing into the substrate. Lastly, the printers and the inks are very inexpensive, the system requires little maintenance, and so the overall cost of ownership is very low compared to other marking technologies.

The drawbacks of valve jet include the include slow speeds of 200 feet per minute, and very low resolution, which is usually limited to about 10 dots per inch. The print height is limited to about 3/4 inch, and printing fonts smaller than 1/2 inch are not possible. Therefore, only alphanumeric characters can be printed with valve jet – no barcodes, or logos. Also, the substrates are limited to porous types, although recent developments include solvent/ evaporative ink which broaden the application space. Lastly, like other liquid ink based marking systems, valve jet can be messy.

The ideal application for valve jet technology is carton coding such as that put onto corrugated cartons and trays.

Thermal Transfer

Thermal transfer printing uses a digital thermal printhead, together with a thermal transfer ribbon to create an image on a substrate. Thermal transfer ribbon is a thin film of solid, meltable ink coated onto a Mylar® carrier made of very thin poly (ethylene terephthalate). When the printhead elements are on, the ink melts from the carrier film, and is transferred hot to create an image on a substrate. The ink then rapidly freezes upon touching the substrate. Figure 9 shows a thermal transfer ribbon code and Figure 10 shows the thermal transfer marking system.

One of the biggest advantages of thermal transfer printing is the high resolution. As a result of this, print density and contrast are excellent, making this technology capable of printing a variety of alphanumeric characters, logos, and barcodes. The print area is as large as 4 inches wide by 3 inches long. Due to the ability to print on a wide variety of flat substrates, possible applications include label stock, primary product, shrink wrapped products, corrugated cases and pallets, etc. In addition, since there is no liquid the process is very clean and environmentally friendly.

The drawbacks of thermal transfer are that the speeds are limited to about 300 feet per minute, which is generally much slower than many ink jet technologies. Since thermal transfer is a digital contact coder, the system requires a well-controlled substrate. It works well on paper and plastic packaging films and very flat plastic substrates, but will not work on metal, glass, or curved plastics. The pressure between the thermal head and the part must be precisely set, and rigid parts must be perfectly flat. Also, the cost per print tends to be higher, and there is a downtime cost associated with having to change over the ribbon.

Thermal transfer (TT) finds a lot of use in bagged food products that are usually packaged in plastic film bags such as nuts, coffee and potato chips. Another good fit is in print and apply labels for cartons and pallets. These labels are commonly used along with barcodes to provide tracking information.

The focus of the paper will now switch to a non-ink based digital marking system – laser.

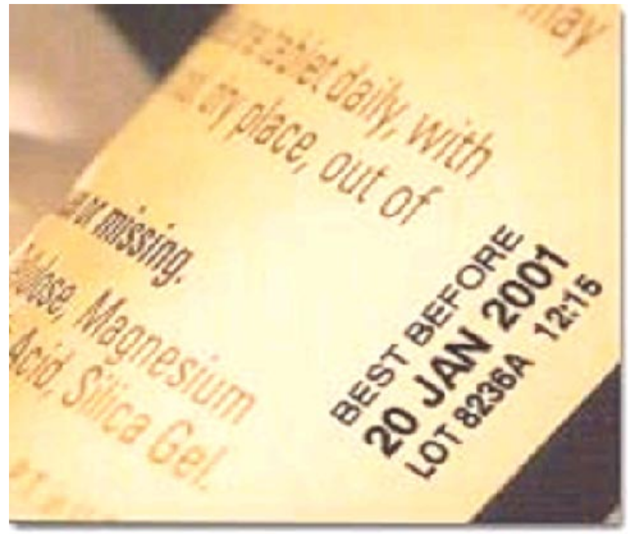

Figure 9. Code from a thermal transfer marking system

Figure 10. A thermal transfer printing system.

Laser Technology

Lasers have been incorporated into a non-contact printing system that uses low power CO_2 laser irradiation, of a specific wavelength, to ablate material off the surface of a product or substrate. The mark or code is formed by the pattern of ablation. This process uses no ink or other image-forming supplies. Figure11 shows a typical laser sample print, and Figure 12 shows a photo of a laser coder.

Figures 11. A typical laser sample print.

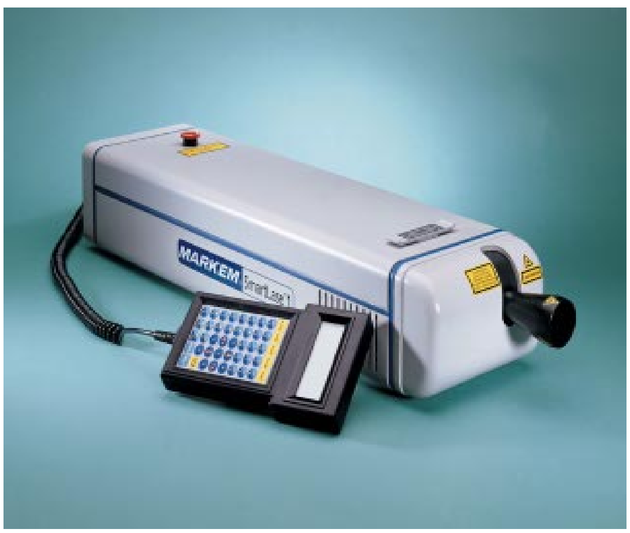

Figure 12. A Laser Coder for Industrial Marking

The main advantage of laser is the permanent marks that are achieved through ablating away part of the surface. No inks or consumable supplies are used, resulting in a low cost per print. Add in the high reliability and the net effect is a low cost of ownership. If only one line of text is used then speeds of up to 300 feet per minute can be attained. However, if more than one line of text is used, then this speed drops dramatically.

The biggest drawback to laser is that on clear or light colored substrates, a very low contrasting mark is produced, that is difficult to read. Substrates are limited to chip boards and poly(ethylene terephthalate) (PET), since this is also a destructive marking process. Direct laser has very limited capabilities on thin film substrates, metal, paper or glass. Either the laser burns holes into the substrate or the surface will not ablate. Environmentally there is both good news and bad. Though there are no solvents used in laser technology, the lasing process creates fumes and dust which requires ventilation. Also the potential hazard of the laser light to the eyes must be guarded against exposure. The resolution of some lasers for industrial marking is limited to 5 × 5, 5 × 7, 10 × 16 dot matrix, and so characters are limited to alphanumeric and barcodes – although some lasers with smaller spot sizes can create logos, or symbols.

Overall, the best fit for laser technology is on PET beverage bottles and surface printed chipboard cartons such as cereal boxes. Other growing uses of lasers include marking on printed circuit boards to replace specialty high temperature labels.

Conclusion

Table 1 shows a summary of the advantages and disadvantages of all the technologies that were reviewed in this paper. A double + or – sign represents a strong advantage or disadvantage, respectively, whereas a single + or – represents a slight advantage or disadvantage.

Table 1. Advantages and Disadvantages of Digital Marking Technologies

	DOD Ink Jet	CIJ	Valve Jet	Laser	Thermal Transfer
Throw Distance	-	++	+	-	-
Print Speed = 1000 ft./min.	++	++	-	-	-
Resolution >300DPI	++	-	--	-	++
Environmentally Friendly	++	-	+	+	+
Substrate Adhesion	-	++	-	+	+
Mess	+	--	-	+	-
Cost Of Ownership	+	+	++	+	-

As end users need to put different types of codes and marks on their products, they need to work with suppliers of digital printing equipment to understand the requirements of their applications. By documenting the fixed parameters and prioritizing the variable ones, a printing solution can be chosen that best suits the end user's needs. This assessment includes the range of product types, substrates that will be marked, the quality and reliability needs for each product, and the desired cost per print/cost of ownership. Fortunately there is a wide variety of digital marking technologies available to the end user with specific advantages and disadvantages. Hence a practical digital marking solution can be found by weighing the product marking requirements against the capabilities of each technology.

Biographies

William R. Dougherty received his B.S. and M.S. degrees in Polymer Science from the Pennsylvania State University in 1982 and 1985, and a Ph.D. in Polymer Science from Lehigh University in 1999. From 1985–88 he worked for NL Chemicals developing polyester resins for coatings. From 1988-2000 he worked for Air Products and Chemicals developing additives, resins and emulsions for many types of coatings, inks and adhesives. Since 2000 he has worked as the Chemical Product Development Manager for Markem Corporation in Keene, NH, focusing on ink development. He is a member of the American Chemical Society.

Ann Reitnauer holds a B.S. degree in Chemistry from Russell Sage College. She is currently a principal chemist, product development at Markem Corporation. Recent projects have included the development of specialty hot melt drop-on-demand jet inks and Touch dry rolls for the packaging industry. She holds four patents covering various hot melt ink formulations. Prior to Markem, Ms. Reitnauer was associate chemist at Inmont Corporation working on the formulation of specialty water-based flexographic inks for packaging films and paperboard.