Development of an Inline Digital Printing System for Industrial Packaging Applications

Henry M. Dante and Georgios Karles
Philip Morris USA Research, Development and Engineering
Richmond, Virginia

Abstract

In this paper, we describe the development of an ink jet printing system for applications in industrial package printing. With the phenomenal success of the ink jet printing technology in the SOHO environment, we have witnessed several efforts from both ink jet printing system manufacturers and the packaging industry in using this technology for packaging applications. In the past, there have been some applications of ink jet technology in packaging, especially for low resolution and low speed applications like case coding, bar coding and the like, with continuous ink jet being the main technology of choice. Currently, the DOD technology has matured to the extent that it is becoming the preferred technology for high quality and high resolution printing systems. We believe that ink jet technology, through recent advances, has reached a stage where it could be used to develop printing systems for applications in package printing. These applications can span the range from printing just variable information to full package printing. We will give details about the packaging application from the end user's perspective and address issues such as resolution, speed, reliability, etc. Also considered are issues like environment, user interface, manufacturing integration, and acceptance on the factory floor, which are all key elements for the successful implementation of the technology. We will detail our experience over the past couple of years as an end user trying to incorporate this technology and the lessons learned in the process.

Introduction

Over the recent past, there has been an explosive growth in the application of ink jet technology in different applications including small office home office (SOHO) printing, textile printing, as well as some customized printing applications, like mailing labels. The next logical application for this technology is in industrial package printing for consumer products and the like.[1,2] The application of digital printing technology, in particular ink jet technology to consumer packaging opens new ways to customize the packaging, thus opening new avenues for product promotions and marketing.[3] Ink jet technology is ideally suited for such applications provided it could meet the quality and the throughput requirements for these applications. There have been some attempts in the past to use this technology for packaging applications, but it is only the recent advances in technology developments that have made it possible to meet the demands of some of these applications. One more crucial factor for any successful system development is necessity for the direct involvement of the consumer package goods industry, as this industry defines the requirements as well as provides the logistics for successful integration of the technology with the manufacturing system. In this paper, we describe the development of an ink jet printing system for consumer packaging applications, and detail the lessons learnt during the development.

Any successful adaptation of a technology and development of new products based on a new technology requires a thorough understanding of the demands placed on the new system by the application and acceptability by the customer. In the case of digital printing technology, it is also worth noting that apart from the different quality issues associated with various packaging applications, some of these requirements depend upon where in the packaging process the digital printing is planned to be implemented, as well as how much of the printing will be done using the digital technology. Ideally, a complete system with an integrated printing and packaging operation will provide the most flexible platform for product customization and manufacturing flexibility. However, at present this goal is beyond the reach of the technology, and a hybrid system employing traditional printing and digital technology in the packaging process is an option which will provide many attractive benefits. It is important to realize that even in a customized packaging application, the whole of printing does not change from copy to copy. Some of the information is fixed among all packages, and only some of the information keeps changing. Thus, one of the ways in which the digital technology could be utilized is by using it only to print the variable information at an appropriate point in the process. Though the throughput and the print quality issues depend upon the particular packaging applications, we could get some general guidelines for specific applications. For example, most packaging applications use Gravure or Offset printing and the printing is done in very high speed presses. The efficiency of these traditional printing techniques is due to the speed of printing as well as the dependable quality and reliability. The digital technologies can not compete with these systems for fixed high volume applications. However, as we will describe subsequently we could incorporate digital printing to do what it does best, i.e. to print variable information.

Among the two types of ink jet technologies, i.e., continuous ink jet (CIJ) and drop on demand ink jet (DOD), the CIJ technology has had some success in

applications relating to industrial printing like date and bar coding, and personalized mailing systems.[4] Of late, the DOD technology has started to make inroads into some of these application areas.[5] There are many advantages of using the DOD technology including simplicity, affordable cost, reliability, availability of more ink formulation options and much higher print quality. Some of the issues that need to be addressed are drying times, water and abrasion resistance, reliability and speed.

Conventional Package Printing

The current packaging systems utilize pre printed materials which come either as large label rolls (used in packages known as soft packs), or as blanks (used in packages known as hard packs) in units of a few hundred. The feeding mechanism of the packaging/printing system depends upon whether label rolls or blanks are used. Large numbers (typically hundreds of thousands or millions) are printed using traditional printing techniques. When the volumes are large and if the printed information on the packages does not vary, the traditional printing is very cost effective. When the production schedule can be fixed in advance, the system works quite well. But in practice, changes in supply and demand mean that production schedules change frequently. Last minute changes are a rule rather than an exception, and as a result, a large amount of buffer stock of the packaging material has to be maintained to accommodate these changes as and when they occur. So in consumer packaging industries, it is common to have large warehouses filled with the pre printed packaging materials. Such storage means inventory maintenance and tracking as well as significant wastage due to excess materials and obsolescence in graphics or materials due to aging.

From the foregoing discussion, it is very clear that if package printing could be incorporated during the packing operation, then there are several advantages which result in significant cost savings. Though this fact has been recognized for some time, it is only now that the developments in technology have made it possible for major players in the industry to seriously consider this option. An understanding of the strengths and the limitations of the digital technology, and incorporating this technology in an intelligent manner will assure success. However, significant investments and developmental efforts need to be made before the technology will be mature enough to meet the needs, and gain widespread acceptance. The advantages of flexible printing/packaging will provide significant competitive advantages as well as new ways of marketing and customization for early adopters of this technology.

Packaging Options

In packaging applications, a variety of materials are used, the most common being paper and plastic. Among these, paper may be the most widespread material in different forms like soft packages, hard packages, cartons and cases. Apart from holding and protecting the product, the packages also serve as decorative and advertising media for the products they contain. After gaining an understanding of the manufacturing and packaging process as well as the ink jet technology, we decided to target paper packaging as it provides the most potential for implementing the digital printing technology. The type of packaging machinery will vary depending upon whether soft packages, which use roll labels, or hard packages which use hard blanks are used. The variable information in these packages is usually limited to a portion of the printing on the package. Typical examples of the variable information being date and bar codes, ingredient information, region or country specific codes, or different languages for the global and export markets. Once the technology is successfully implemented, it could be used for other marketing and promotional applications as well.

As we already mentioned, the speed and resolution requirements vary greatly depending upon the product and package in question. The range of requirements that we targeted is as follows: Product speed ranging from a few tens to several hundred pieces per minutes, the most common speeds being 100-300 per minute. Resolution ranging from 200 dpi to 600 dpi (achievable with Gravure or Offset printing), with good abrasion and water resistance as well as fade resistance. Generally speaking, pigmented inks are necessary to meet these requirements. If the digital printing unit is appended to the packaging machinery, then it is imperative that it also meet the throughput requirements of the product line. Some of the other issues to be considered are the drying time for the ink as well as any residual solvent retention which may not be acceptable, and material handling on the factory floor.

Digital Printing Implementation Options

Digital printing system could be incorporated in the industrial or consumer packaging process at different steps in the process. For complete flexibility, printing should be incorporated as a part of the final packaging step. Such a system will provide total flexibility, as the printing could be changed on the fly, providing all the advantages of a truly on demand printing/packaging system. However, the printer and the packing unit are, in such a system, completely tied together with the result that any problems with the printer will shut down the whole unit. Moreover, such a system will need real time on line inspection to verify the integrity of the printing, which adds more complexity to the process. Some of the other issues to be considered are the drying times, need to vent solvents, and material compatibility of any residual solvents from printing, etc. The second option is to have a just in time printing operation close to the final packaging operation, but separate from the packaging unit itself. Such a scheme will not provide the complete flexibility of a print/packaging unit, but provides many advantages compared to the conventional process. The last option is to incorporate digital printing along with the conventional printing systems in a hybrid unit, and use the flexibility offered by the digital printing at the conventional printer itself. Among the three, this scheme is the least flexible and provides only a few advantages. However, such a system might provide the necessary throughput and customization required for some applications. Though less flexible compared to the other two, in such a scheme

printing and packaging steps are separate, and will not result in shutting down the packaging unit every time problems arise in the printer.

Elements Required for Success

It is needless to say that if the technology has to be incorporated, then any additional demands the technology puts on the process and the operator have to be more than offset by the impact the technology has in terms of return on investment (ROI). However, it should be realized that there is a paradigm shift when digital printing is incorporated, providing additional opportunities for customization and marketing, whose impact on the business is as yet intangible, but certain to be quite substantial. Some of the elements that are required for success are enumerated in the following: Since the packaging also provides an image for the product and works as an advertising/marketing tool as well, the quality achieved by the new technology should be comparable to the current quality standards. This requirement may be relaxed in some cases where only a small portion of the printing is digital, i.e. date or bar coding for example. If the implementation is done on the packaging unit, then it is necessary that the unit be seamlessly integrated. Moreover, the operator should not be burdened with additional tasks due to the added piece of equipment. The system should be reliable enough as not to adversely affect the reliability of the packaging unit and should not reduce the throughput. The system should be compatible with the overall process control and automation of the packaging unit. It should be easy to operate and service, so that the operators do not have to go through complex training for its operation and maintenance. It should support quick changeovers of different brands, and be easily replaceable and upgradable. These and other technical requirements are summarized in table I below.

Ink Jet Technology Options

It has been already pointed out that multi deflection continuous ink jet technology has been successfully used in packaging applications for printing limited information like date coding. However, the quality of printing from this technology is very poor. The binary CIJ systems could provide better quality and throughput, but are extremely difficult to incorporate in a production environment. It might be suitable for a hybrid printing system where the variable information is printed at the converters. Drop on demand technology shows the most promise, and with new technology development and system integration could be incorporated in an integrated print/package system.

As is well known, there are two types of DOD ink jet technologies, thermal and Piezo. We think that the recent advances in Piezo technology have made it possible to use this technology in an integrated print/package unit.[5] Some of these developments are the reliability of the technology, as well as the fact that the printheads last for billions of drops, and can jet several gallons of ink reliably. Piezo printheads are currently available from different vendors with number of nozzles ranging from about a hundred to about 500. The nominal resolution of these printheads is quite low, from less than about 80 to around 180 in some cases. The maximum print swath available is less than 3 inches. The printheads have been successfully used with a variety of inks, ranging from simple water based dye inks to solvent and oil based UV and hot melt inks.

Table I. Requirements for industrial applications.

Runnability	No missing jets No jamming Uninterrupted run per shift
DPI	About 300 dpi for text
Printing Speed	~ 150 ft/min
Short term periodic maintenance	Once a shift Cleaning cycle less than 10 min
Print Quality	Print density comparable to Gravure Dry time of less than of 3 - 10 sec. depending on application No smearing Print tolerance/registration of 0.03” No satellites
Robustness	Print independent of fluctuations in packaging environment Print adjustment available Printer integratable with current process control
Ink	Compatible with environmental and any other (e.g. regulatory) requirements
Auxiliary Systems	Vision control for print verification and rejection if needed

Prototype Printer System

Fig. 1 shows the block diagram of a printing unit, which could be appended to the front end of a packaging unit that uses blanks. The unit is designed to be in a modular fashion as modular approach provides several advantages. One of the key advantages is that the various modules could be custom designed for the particular packaging unit. It also provides additional flexibility to incorporate more modules like an inspection system, a curing unit, etc. As far as the packaging unit itself is concerned, its operation is hardly changed as it still depends on the blank feed from the conveyer belt in the front. The operator will do the same blank loading operation, only in this case, the blanks will have regions spared out so as to receive digitally printed variable information. For a practical system, we need a print swath of at least an inch or more, with about 2 inches perhaps being suitable for many applications. This means that to achieve the required resolution, printheads have to be stitched together. Much of the system integration effort will go towards engineering the printhead stitching and the blank feeder mechanism. A post drying unit might have to be incorporated to facilitate drying as the drying time available is limited. A vision system to inspect the print may also be necessary to assure good print quality. A mechanism to reject any misprinted blanks need also be considered.

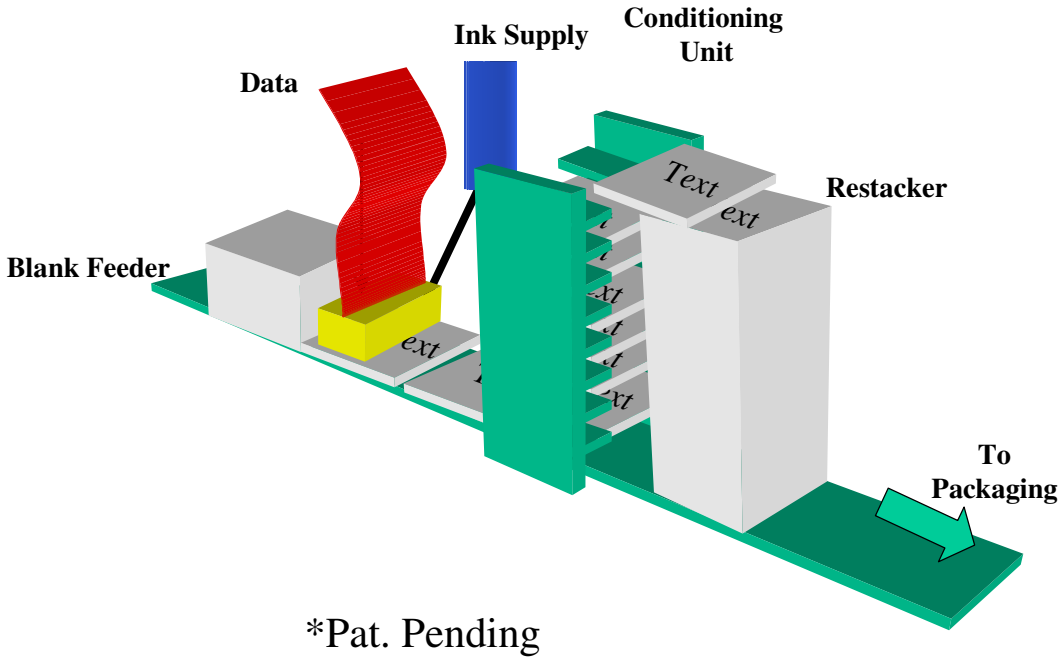

Figure 1. Schematic of the prototype printer for printing variable information on packages.

We designed the system to provide a print resolution of slightly more than 300 dpi, which provides the necessary quality required in packaging applications. A print swath of 2.25" is obtained by stitching 3 printheads together. However, if the print quality and print swath requirements are different, then the modularity of the system allows for using different printhead design, stitching more or less printheads as the case may be. If multi color printing is required, then several printhead assemblies could be used, each printing one color.

The requirements for the ink depend upon the application and the product. Generally speaking, the ink should be formulated using environmentally friendly and nontoxic ingredients. Also, as previously mentioned, in order to provide the necessary quality and attributes, pigmented inks have to be used. The requirements of keeping the nozzles open by using slow drying inks have to be balanced against the requirement to dry quickly in an application environment.

One of the key elements to be solved before a system could successfully be developed is the drying time requirement and meeting this requirement in the printing unit before the package blank goes to the packer. We have solved this problem in an innovative way by developing a drying tower, which provides the necessary drying time to the printed material. At the high packing speeds, it is necessary to separate the blanks for the required drying time before they come into contact with each other or the packer. The drying tower in the system provides this by moving the blanks in a staircase like structure, thus keeping them separate while they are wet. The stacker unit could be implemented in a number of ways. The drying tower could provide stacking for several dozen of the blanks thus providing necessary dry times of several tens of seconds. Airflow and heating could be provided in situations where very fast drying times are required. Once the package blanks are printed and dried, they are re-stacked in the front end of the packaging unit. Depending upon the application, the system could be designed to stack a few hundred or several thousand of these blanks. This re-stacking of the blanks also provides a buffer stock of the printed blanks in case the system needs to be serviced for a few minutes, e.g., for clearing jam or purging the printer.

Some of the auxiliary modules that could be incorporated within the framework of the system are a pre heating unit to heat the blanks before printing to enhance the print quality, a hot air knife to help in the drying, and a vision inspection system to inspect the print. The modular design of the printer system makes it possible to incorporate these and other additional units, thus making the system extremely flexible. Flexibility provided by the modular design is a key element in the design of the system. As those in the manufacturing industry will realize, the packaging units come in many different forms depending upon the application, and it will be necessary to adapt the printer to suit the particular environment.

References

1. H. M. Dante, G. Karles, and A. K. Basak, "Digital Printing in Industrial Packaging Applications: Current Status and a Roadmap for Success", IS&T NIP16, Vancouver , 2000.

2. W. Baxter, "The Spread of Ink Jet Printing Onto Packaging", 3rd Annual Industrial Ink Jet Printing Briefing, IMI, Florida, 1999.
3. P. Williams, "The Color Opportunity in Industrial Ink Jet", 3rd Annual Industrial Ink Jet Printing Briefing, IMI, Florida, 1999.
4. N. Stokes, "Ink Jet Technologies and Their Applications", 3rd Annual Industrial Ink Jet Printing Briefing, IMI, Florida, 1999.
5. P. Frost, "Piezoelectric Ink Jet Technology Ready to Dominate Industrial Applications", 3rd Annual Industrial Ink Jet Printing Briefing, Florida, 1999.

Biography

Henry M. Dante is currently at Philip Morris research and development where he is responsible for implementing digital printing technologies. He received his Ph. D. in Electrical Communication Engineering from Indian Institute of Science, Bangalore and worked as a faculty member in the Electrical Engineering Department at KREC in India and at Tufts University, Medford. He has been with Philip Morris from 1988 where he has worked on developing vision systems, process control, modeling and simulation and implementing new technology.

Georgios Karles received his Ph.D. in CHE from the University of Texas at Austin in 1990. He then worked at the University of Texas as a postdoctoral fellow investigating heterogeneous catalysis. From 1992 to 1997 he was with International Paper in Tuxedo, NY working on developing papers with tailor made properties through chemical or physical modifications. George has been with Philip Morris since 1997 working on specifications for packaging materials and assessing and implementing new packaging and printing technologies.