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Challenges of Digital Ink Jet Pigment Textile Printing

Dr. Ray A. Work, III
New Business Development Manager, DuPont Ink Jet Inks
Barley Mill Plaza, Wilmington Delaware

Abstract

Digital ink jet pigment textile printing offers both opportunities and challenges when compared to traditional screen-printing. The application of colorant to textiles by ink jet printing is very different from screen-printing and the ink-fabric interactions produce different results. Ink jet pigment printing provides a very different set of printing and end use characteristics in the printed textile compared with traditional pigment printing techniques. In each of these aspects of ink jet pigment textile printing, there are potential advantages as well as challenges as the industry moves forward to embrace these new processes. This paper will address several of these differences, provide a review of the current state of the art and offer a perspective on potential future developments.

Digital Printing verses Analog Printing

Analog printing uses a "master", for textiles this is usually an imaged rotary or flat bed screen. The image to be printed is separated into patterns of consistent color and screens are made one for each different color to be printed. A screen may be prepared by digital techniques but it ultimately becomes an analog "master" from which prints are made. Generally printing is performed by pushing paste-like inks through the open pores of the screen onto and into the fabric being printed. Each screen is placed sequentially onto the textile being printed and different colors are applied separately. The result is a design generally made up of a relatively small number of "spot" colors, which together make up the printed design.

With digital printing no physical "master" is produced. Each image element in the final printed textile is an individual spot of ink applied by a digital printing process, in this case ink jet. Ink jet printheads pass over the fabric and deposit one or more droplets of each color of ink required in a pattern designated by the computer driving the printheads. The "virtual master" resides in the computer memory. Generally "process" color, that is cyan, magenta, yellow and black, inks are used to produce the colors required by the design. This "process" color approach produces the final color on the textile by mixing the primary colors on the textile sequentially rather than being premixed in an ink kitchen prior to the printing process. With screen printing the inks may be dried between colors. With ink jet all colors are printed simultaneously, wet on wet.

As executed today, digital ink jet printing utilizes this "process" color to achieve the wide range of colors required by the designer. Analog textile printing uses precisely premixed spot colors. These two very different approaches to printing result in very different printing attributes. Exact color matching and a wide color gamut are difficult to achieve at ink jet technology's current level of development compared to that achieved by analog printing. In most cases "process" color inks use only three primary colors and black to produce the desired color on the textile. In a few implementations 6 or 8 colors are used. Inks are blended on the fabric by printing the primary colors drop by drop sequentially over a small area to achieve the desired color. In most cases the color increments represented by single drops are too large to give the correct mixed color. For that reason a larger area of fabric is chosen and the ink drops are applied over that area to give "average color" which best matches the correct color. This "dithering" and the effects of printing sequentially cause non-uniformities in the color on the fabric in many instances, which may be objectionable. In addition, the color gamut is restricted by the mixed colors attainable using the available primary colors. With screen printing as many as 10-12 primaries, mixed in any proportion, give the precise color desired. Since they are pre-mixed they do not suffer from variations due to order of printing the primaries. This gives screen printing the advantages of a closer match in color, less variation in color in solid areas and a "cleaner", brighter color with less gray component to the mixture. Process color involves subtractive color. Each primary, cyan, magenta and yellow, must be transparent so that the light passing through one color ink will not absorb or scatter the light from another color ink beneath it. Pigments must be chosen which are inherently transparent and they must be reduced in particle size to less than half the wavelength of light. Larger particles will scatter light and cause "graying" making it appear dull and dirty looking. This is a much smaller particle size than is usually found in commercial spot color inks used in screen-printing. This attribute is also important when one wants to print variable information on colored materials, like logos for example. Process color inks will not hide the underlying color since they are transparent.

Digital ink jet printing can print a much wider variety of colors on a single print than is cost effective with screen-printing. There is no incremental cost for adding additional colors to an ink jet print while for screen printing an additional screen must be produced for each additional color in a pattern. Digital printing can better reproduce computer-generated designs. Today fabric printers must adapt the designs provided to them to an economical number of spot colors for production using screens. With digital ink jet printing this limitation does not exist. Even photographic-like images can be printed in realistic color using digital ink jet printing. These advantages are important. More important, however, is the ability to change designs quickly. The design and colors can be changed by sending different electronic pulses to the printheads. This compares favorably to the laborious process of cleaning screens, changing screens and inks. Another important design attribute compared to rotary or flat bed screen-printing is that the design need not have any given repeat or length dictated by the diameter or length of a screen.

Ink Jet Digital Printing

In the current state of development ink jet printing provides far lower print speed than analog printing by several orders of magnitude. It fits well today the sample, customization, and very short run markets. Increased printing speed will be needed before it can effectively address the main stream textile markets.

Reliability of the ink jet printing systems available today has improved dramatically over that of only a few years ago. This demonstrates how rapidly improvements can be made. To achieve the higher speeds required to transform the market; additional work on effective reliability will be required. As the numbers of nozzles and their drop firing frequencies have increased the demands on reliability increase as well. Reliable printing is fundamentally a function of three parts of the system:

1. The printhead and its maintenance system
2. The ink and its ability to avoid clogging
3. Redundancy in nozzles allowing non-performing nozzles to be replaced by functioning ones and/or randomization of defects to render them invisible.

Whether pigment or dye based, these problems remain perhaps the most demanding challenge faced by ink jet production printing. Steady progress is being made in both the avoidance and curing of defects. Today the use of scanning heads and mass parallelism of automated printers by the Seiren Corp. of Fukui Japan provides an existence proof of this capability. They provide the first publicly disclosed example of true production printing by ink jet since the Millitron very low resolution printer used by Milliken to print carpet more than 15 years ago.

Let's now consider the ink and the way the ink interacts with the textile. Ink behavior is totally different in ink jet compared to screen-printing. Ink jet inks must be very low viscosity and water-like in consistency. Screen inks are paste-like and behave very differently on the textile. Bleeding and penetration properties of the two are very different. This poses a very complex problem when added to the different weights and types of fabrics being printed. Fabric unlike paper is a three dimensional structure and the ink and colorant requirements vary over a large range. Cotton knit will require several times more ink than silk voile to achieve the same color. In screen printing the squeegee, the colorant loading, the pressure on the squeegee and the viscosity of the inks may be varied over a large range of values to allow for these differences. They are adjusted to achieve the desired color and penetration while maintaining good bleed performance. With ink jet, changing the viscosity is not an option since it is dictated by the printhead. Changing the colorant loading in the ink requires flushing of the system and a change over in the ink supply. So practical limitations exist on the range of fabrics that can be produced with a single ink set. On some fibers that are absorbent, like wool and cotton, the ink is absorbed quickly and easily so bleeding of the water-like ink jet ink is minimized even without a pretreatment. Unlike the thick paste-like ink used in screen-printing these water-like inks will bleed badly on non-porous fibers like polyester and nylon. A mechanism to control bleeding must be incorporated to avoid the ink wicking along the non-porous fibers of the textile. In traditional printing this is controlled by the high viscosity of the inks used. With ink jet printing pre-heating the textile or addition of a fabric pretreatment may help avoid this problem. The binding mechanism of the pigment to the textile may utilize both ink chemistry and a complimentary pretreatment chemistry to achieve the optimum result. The bottom line is that the ink, textile and the printing system must be designed to control bleeding while achieving the hand, correct color and fastness required by the intended application.

Pigmented Ink Jet Inks

Pigmented ink jet printing is relatively new in the world of ink jet printing. Only since mid-1996 have color pigmented ink jet inks been made commercially available that enable high-resolution process color pigment printing. These initial products were developed primarily for improved light fastness on paper and film substrates. Warranties of up to 2 years for outdoor use are now offered when these pigmented inks are used with matched media and overlamination films. In textile printing the needs and incentives are largely different (except for outdoor signage applications). Here the main driving force for choosing pigments instead of dyes is the elimination of wet post processing needed for fabric dyeing. Pigment printing promises lower cost of both materials and processes compared to dyes. By eliminating wet post processing, ink jet pigment printing has the potential to make "agile manufacturing" much more attractive. "Agile manufacturing" is a term coined by TC^2 of Cary NC and refers to an integrated, on demand, order and fulfillment process which includes the textile printing and apparel fabrication manufacturing processes. To implement "agile manufacturing" one must have the ability to print, cut, sew and ship immediately on demand. This capability can dramatically change the way apparel and other printed textiles are produced. Freedom from the requirement of using wet chemicals along with "agile manufacturing" will facilitate "distributed printing". "Distributed printing" refers to small textile fabrication facility that receives the design and product information electronically then produces product at or near the retail outlet. With these capabilities along with the digital design, the potential cost savings in the supply chain and the reduction in inventory and design risk, the availability of digital ink jet pigment printing should drive conversion of some parts of the textile printing industry away from screen printing.

With dye based ink jet inks the chemistry of binding of the dyes to the fibers remains basically the same. Pretreated fabric to provide bleed control, chemicals for effective reaction with the fibers, wet post processing to react the dye with the textile and wash away excess dye and other materials from the fabric all require printing in a printing plant environment. With pigment based ink jet printing the true advantages are only achieved if wet post processing can be avoided. In addition the applications expand dramatically if one can take advantage of the option to minimize the stiffening which accompanies most pigment printing using screens. In screen printing the pigment is mixed with binder and thickener to give a paste like ink that is applied under pressure with a squeegee to and through the fabric through the screen. The ink is then dried and it becomes bonded to the fabric. To achieve the properties necessary for this application process, a lot of extra solid material must be included in the ink. A larger solids content and more ink is used than is necessary to provide color and bonding to the textile. The resulting excess of dried ink material increases the stiffness of the fabric. The stiffness affects the drape and "hand" properties in a negative way for many applications. Since a major driving force for screen pigment printing is its low cost, the pigment particles used are frequently relatively large and accompanied by impurities. Further particle size reduction and purification add additional cost. Pigments used in those applications requiring light fastness are chosen first for their light fastness and second for their color. This frequently results in dull colors with pigment printing in the traditional printing process.

These problems need not result if pigmented ink jet ink is used instead of screen printing ink. No bulk thickeners, no impurities and no large particles are among the required specifications for the ink jet process. The minimum amount of pigment, small pigment particles and minimum necessary amount of binder are used to allow ink jet to provide the print head reliability required and to give transparent process color on the fabric. Drape and "hand" can be improved significantly and color quality improved as well.

Several methods can be used to achieve the bonding of the ink jet ink to the textile. Traditional chemistries like radiation curing and heat activated curing both cross-links and/or coalesce the binder to encapsulate the pigment and bond it to the fibers. The bonding mechanism might be included in a treatment on the textile rather than depending totally upon the ink for all of the functionality. An example of this is the treated fabrics sold by Asahi Glass Company of Japan as part of their Pictorico® product line. These fabrics bond the pigmented inks without the use of significant binders in the ink making them suitable for thermal ink jet printers.

Perspective on Future Developments

The future is bright for ink jet digital textile printing using pigments. Several approaches appear feasible and are currently available or are under development. The choice as always will be made based on the end use requirements. Paint-like inks may be used when "hand" considerations are not important. Treated fabrics may be chosen when bleed control is required or thermal ink jet printers are chosen. Pigmented ink jet ink formulations with high print reliability have been developed and are being adapted to textile printing. We expect that "agile manufacturing" and "distributed printing" will be a reality for some applications in the near future as equipment manufacturers develop the printers to meet these needs.

Biography

Dr. Ray A. Work, III is currently New Business Development Manager, DuPont Ink Jet Inks, Wilmington, Delaware, USA. Dr. Work received his B. S. degree in Chemistry from Auburn University, Auburn, Alabama in 1966 and Ph.D. in Physical Inorganic Chemistry from Louisiana State University, New Orleans, Louisiana (now the University of New Orleans) in 1971. Following a Post-Doctoral Fellowship at the University of Hawaii-Manoa, Dr. Work joined DuPont as a research chemist at the DuPont Experimental Station in Wilmington Delaware in 1972. Since joining DuPont, he has held a wide variety of positions over the past 25 years. These include research, research management, business management, product development management and market development management. Dr. Work holds 12 US patents, has published 30 technical papers and is a frequent speaker at conferences, symposia and workshops worldwide on the subject of ink jet inks.