Equipment type and ink technology are among the many factors to evaluate for delivering the appropriate product. Courtesy of Image Options.

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Digital Textile Considerations

Determining the right process and technology based on markets and applications of interest.

Digital inkjet production is rapidly replacing many of the historical analog production methods for fabric decoration. Whether it was the screen printing of banners, flags, T-shirts or the rotary press printing and dyeing of contract fabrics, digital inkjet printing has transformed many industries.

The ability to move quickly to a finished product or fabric sample and produce one-off custom designs in single or many units has influenced the decision of many companies to embrace the digital process. Digital inkjet has simplified the complexity and reduced the cost to enter various markets. The digital process is more environmentally friendly, using fewer chemicals and generating less waste. Digital requires far less floor space, reduces time to delivery and the potential risks associated with excess inventory, and is healthier and safer for employees.

There is greater flexibility in digital technology. Once printers determine the market they desire to support, they should then evaluate the requirements of a system that will deliver the appropriate products. Systems include type of textile for market, ink technology most suitable for fiber type, printing equipment for the ink type, heat press or calendering equipment if using dye-sublimation direct or transfer, software and process, and finishing equipment.

Ink Technology

Ink technology is a key component of the digital textile system. When selecting ink, it's important to understand suitability of chemistry by fiber type and end use. Textile colorants are categorized as either pigments or dyes. Pigments are insoluble particles that are finely ground and dispersed within a vehicle/binder. During the printing process, pigment is applied to the surface of the substrate and heat is used to activate a binder system in the ink that creates a mechanical bond between the color and the fabric.

Pigments have been slow to develop for digital textile applications given challenges with formulation.

However, they have improved over recent years, and there is now ink technology available for higher-speed, industrial inkjet printers. Since pigments sit on the surface of the substrate, they have an impact on how the printed fabric feels (fabric hand) and they exhibit some limitations in fastness to washing and rubbing. Pigments currently tend to offer a smaller color space and require diligent printhead maintenance to ensure continued jetting performance.

Many of these features are improved with more recent formulations and, in some cases, specialized fabric pretreatments are applied to help optimize appearance and fastness properties. Pigments offer a streamlined processing scenario, and, in more industrial setups, heat fixation is integrated with the printing step. This efficient workflow and improvements in color properties and performance are driving an increase in adoption — particularly for e-commerce business models where turn time is key. Additionally, pigments typically offer good fastness to light, which is an important feature for home décor and for many soft signage applications.

Dye-based colorants differ from pigments in a number of important ways. Rather than bonding to the surface of the fabric, dyes enter the interior of the fiber and form a molecular bond or are physically trapped within the fiber structure. This feature results in a more vibrant appearance and contributes to good to excellent wash and rub properties.

There are various classes of dye chemistry and the type of dye must be matched to the fiber type. Reactive dyes are compatible with cellulosic fibers including cotton, linen, and rayon. Acid dyes are compatible with silk, wool, and nylon. Silk can also be printed with reactive dyes although it is not a cellulosic fiber.

For both dye classes, fabric is pretreated to control wicking during processing and to provide the components required to support a chemical reaction during steam fixation. Steaming is typically an off-line procedure that takes about eight to 10 minutes for reactive dyes and up to 40 minutes for acid dyes. This step initiates movement of the dye into the fiber and provides an environment that enables the bond between the fiber and the dye molecule. In the case of reactive dyes, a covalent bond is formed, while acid dyes form an anionic bond with the fiber. After steaming, the fabric must be washed to remove excess color and pretreatment chemistry. Although this is a complicated processing scenario that consumes water and generates some volume of waste, these dye classes are easier to formulate for inkjet and offer good jetting performance, a large color space, and excellent care properties. Reactive dyes are highly valued for apparel and home décor applications, while acid dyes are most commonly used for nylon flags, silk scarves and ties, and swimwear.

Disperse dyes are specific to polyester and are the most commonly used colorants for digital textile printing. Like pigments, disperse dyes are insoluble particles and they are categorized by their energy level. Low-energy dyes are the group that most printers will be familiar with. These dyes are typically applied to paper and then transferred to the fabric using a heated calender. During the transfer step, the heat causes the dye particles to sublimate, meaning they change from a solid to a gas. The polyester fibers also open slightly, allowing the gas to enter and, as they cool, they return to solid form and become trapped inside the fiber. This process, dye-sublimation, is commonly used for soft signage applications, athletic apparel (including polyester swimwear), and home décor. Higher-energy dyes are less commonly used and require more energy to drive the dye into the fiber. They are typically applied directly to the fabric and have greater fastness to light, making them more suitable for outdoor fabric applications and specialized categories like automotive textiles. When applied directly, the fabric is typically pretreated to control wicking during the printing process.

Pigments, which offer good fastness to light, are ideal for home décor applications. Courtesy of Spoonflower.

Printable color space is an important consideration in colorant selection. While dye-sublimation often relies on a standard process color arrangement (cyan, magenta, yellow, and black), other colorant systems typically involve the use of six to eight colors. Gamut-expanding hues may include orange, blue/violet, green, and/or red. Gray is commonly included to aid the generation of smooth tones and reduce dithering in lighter shades.

Printer Hardware

When deciding on a printer for digital textile applications, machine cost and print capacity are front and center. Hardware solutions for textile applications range from modestly priced, slower-speed solutions (less ▸

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than 30 yds/hr) to more industrial, high-speed technologies (more than 100 yds/hr). Some vendors offer a platform that enables purchasers to graduate into higher-speed options as they grow their business, while others select to focus on an application area such as dye-sublimation or pigment. Vendors may also focus on a particular class of technology, such as slower/lower-cost solutions that allow users to grow by purchasing additional units of the same machine type.

Faster printers are a direct result of advancements in printhead technology, including the development of arrays that have increased the dimension of material covered with each pass of the printer carriage. At the highest end of the spectrum, textile companies are investing in single-pass solutions that provide print rates more typical of the rotary screen environment.

Beyond print speed, equipment is engineered for applying ink directly onto the fabric with pigmented ink, or in the case of dye-sublimation, printing directly and/or indirectly, using a transfer method. Within the realm of direct printing, higher-speed technologies are engineered with belts for transporting and stabilizing the fabric during the printing step. Adhesive is applied to the print belt so fabric will temporarily stick to the surface. As the printed fabric or transfer paper advances forward, it's lifted away from the surface of the belt and enters into a dryer and then a winding unit. Washing systems positioned on the underside of the belt are typically activated during printing and clean the belt as it rotates. More sophisticated solutions offer brakes for tensioning the substrate, and scroll rollers and slat rollers for spreading and heated press rollers. These features contribute to the smooth entry of fabric onto the tacky belt. Additionally, sensor technology is positioned at various points to support the feeding process and to prevent collision between the carriage and the fabric.

Type of fiber and inkjet system based on application.

Textile Applications	Fiber Type			Inkjet System Type*		
	Polyester	Natural Fiber	Other Synthetics	Disperse Dye	Pigment	Other
Display Graphics						
SEG - Silicone Edge Graphics	•	•		•	•	
Banners	•	•	•	•	•	•
Flags	•		•	•		•
Tension Frame Signage	•		•	•	•	
Point of Purchase Displays	•	•	•	•	•	
Light Boxes	•			•	•	
Interior Decor						
Window Coverings, Draperies	•	•	•	•	•	•
Wall Coverings	•	•		•	•	
Wall Art	•	•		•	•	
Bedding - Sheets, Comforters	•	•		•	•	•
Bedding - Pillows, Shams	•	•		•	•	•
Upholstery Fabrics	•	•	•	•	•	•
Decorative Pillows	•	•	•	•	•	•
Fine Art	•	•		•	•	
Room Dividers	•	•	•	•	•	
Kitchen & Table Linens	•	•		•	•	•
Apparel						
Sporting Athletic - Performance	•		•	•	•	
Casual Contemporary - Fashion	•	•		•	•	•
T-Shirts	•	•		•	•	
Socks	•	•		•	•	•
Bags, Backpacks	•	•	•	•	•	•
Accessories - Ties, Scarves, Wraps	•	•	•	•	•	•
Corporate						
Healthcare - Bed Curtains & Dividers	•	•		•	•	
Healthcare - Face Masks, Anti Microbial	•			•		
Sound & Acoustic Panels	•	•		•	•	•
Tension Décor	•		•	•	•	
Contract Fabrics	•	•	•	•	•	•
Promotional Items	•	•		•	•	
Other Applications						
Towels	•	•		•	•	•
Umbrellas	•		•	•	•	•
Sun Shades	•		•	•	•	•
Awnings	•		•	•	•	•
Outdoor Cushions	•					

*Not all applications listed

Digital Inkjet System Type*
Disperse LowE - Low Energy Disperse Dye
Disperse HighE - High Energy Disperse Dye
Pigment - Water Based Pigmented Inks & Latex Inks
Other - Specialty Dyes - Acid, Reactive, Fluorescent

The number and type of printheads and the various technology features included are significant factors that contribute to purchase price and total cost of ownership. While lower-cost solutions may have cartridge systems or refillable reservoirs, more industrial solutions often include bulk ink systems to support uninterrupted printing. These ink systems also include on-board filtration, degassing, and management of vacuum settings. These features work together to ensure reliable drop formation and delivery. In the case of pigment printing, ink recirculation has been a key factor in improving inkjet head life and consistency of jetting properties.

While system advancements have enabled higher volume production, it's important to note that installing, operating, and maintaining industrial solutions requires a higher level of knowledge and skill. However, most vendors of this type of equipment provide training for operation and preventative maintenance, as well as remote and on-site support for maintenance events.

Digital Workflow

Digital workflow is the fourth dimension in the digital textile printing system. Both off-the-shelf and industry-specific software solutions are used for image creation. Prints may be engineered for the shape of ▸

Sewing or other types of fabric-fusing technology may be required to assemble cut pieces into completed products. Courtesy of Image Options.

the product piece, or they may take the form of more traditional textile repeats. Although color separation is not required for digital printing, software is available to support spot color matching and enable the creation of colorways. Standard color management and RIP solutions may be used for digital textile applications. However, the ability to manage up to eight colors may be required. Additionally, printer hardware solutions may have specific data requirements that relate to management of grayscales and repeating patterns.

As print-on-demand business models gain traction, print automation has become increasingly important. Automation connects the e-commerce storefront to the back-end manufacturing environment and enables companies to manage customized imagery and ultra-short run production scenarios. Within the textile space, automated file processing includes prepress steps, but also the ability to generate and submit XML (or similar code) that provides layout instructions and order information. In the case of repeating patterns, the XML would be paired with the separations for the repeating unit and might specify the number of repeats to print in the width and length direction.

Substrate Preparation and Finishing Technology

The need for auxiliary equipment to support the fabric preparation and finishing process is important to consider when mapping the total investment for a digital textile solution. The fabric mill typically takes on standard preparation steps, including scouring and bleaching, that provide a clean, white surface for receiving color.

The pretreatment chemistry for reactive, acid, direct disperse, and/or pigment printing is most often applied at the mill level. However, there are application technologies that have been specifically designed to support digital textile operations, and there's a trend toward solutions that apply chemistry to the print surface area only — as opposed to a traditional pad process that involves immersing the fabric in the pretreatment solution. A surface application reduces chemistry consumption and provides a smaller energy footprint when drying the pretreated fabric. These technologies may also provide a more flexible, on-demand approach to the pretreated fabric supply.

Finishing Technology

Fixation technology for digital textile printing is typically positioned as a separate process within the print operation and takes place after printing. Heated calender systems for dye-sublimation are plentiful and are engineered for processing smaller rolls of material and can be configured for larger "jumbo" rolls of a fabric. Calender systems are sometimes used for pigment curing as well, although industrial pigment printers often have on-board dryers that are integrated with the printer to provide polymerization in-line. Technology for steaming and washing of reactive and acid dyes requires considerable investment if intended for higher volume production. Although traditional textile printing facilities are often equipped with this technology, this investment is one of the key barriers to adoption for reactive and acid dye-based printing among new textile print providers.

In addition to the fixation process, other equipment is required to produce the finished goods depending on the application. Automated cutters use either computer numerical control or lasers to trim printed items to size or shape. Sewing, automated, machine, or various types of fabric-fusing technology assemble the cut pieces into completed products.

Digitally printed textiles is a dynamic and growing market and will be for the foreseeable future. For those looking to enter the industry, it's essential to understand these different factors to ensure they're using the right technology and equipment for their market of interest. ■

Brian Hite has 37 years of experience working with and managing companies in the exhibit, event, and graphics production industry. He is also experienced in driving lean production and sustainable operations. Image Options was the first large-format digital facility in California to obtain SGP Certification. Prior to founding Image Options, he was a senior exhibit industry professional.

Kerry King came to Spoonflower in 2013 and is responsible for project management in areas that include development of strategies for ensuring product quality, technical development of new products, and investigation and implementation of new manufacturing technologies. King also works closely with Spoonflower's product development and factory teams. Previously, she spent more than 15 years with [TC]2, a not-for-profit company that specialized in technology development and supply chain improvement within the soft goods industry. She's an active volunteer in the textile and digital print area and is the current president of AATCC, the American Association of Textile Chemists and Colorists.

Michael Sanders is the director of printable textiles and finishing technology for TVF. He has been part of the textile industry for over 40 years and has extensive knowledge and experience in dyeing, printing, and finishing both natural and synthetic fabrics. His involvement and work with digital textile printing goes back to the early days of the discipline's existence. Today, Sanders sits on boards and expert panels and gives lectures nationally.