The Rapid Evolution of Digital Textile Printing

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Textile printing is a 1000-year-old technology which is in the process of transitioning from analog to digital. New ink technologies are accelerating this transition, opening up a whole range of capabilities and fueling innovation in the clothing and household sectors. Fast turnaround, complex designs, shorter runs, on shore manufacturing and just-in-time inventory are being enabled by this A to D transformation.

Many digital ink solutions are competing in this dynamic market: reactive, acid & disperse dyes offer vibrant, durable colors but require post print washing; dye sublimation has opened up the market for custom textile printing onto white synthetics; direct to garment (DTG) printing has enabled custom printing onto white and dark cotton textiles driven by innovations in pre-treat and ink technology; direct to film (DTF) printing is textile agnostic, enabling crisp, colorful printing onto a wide variety of white and colored textiles; and finally direct to textile (DTT) printing, utilizing aqueous, pigmented ink technology is the most likely successor to high volume analog rotary screen printing. Before we dive a little deeper into these competing ink technologies, let's briefly review why inkjet printing is the preferred digital solution for textiles.

Inkjet has a key advantage over most other digital printing technologies in that it does not require contact with the substrate being printed. Textiles vary widely in surface texture ranging from very smooth silk to very rough wool. Inkjet printheads eject drops of ink which can travel millimeters of distance before striking the substrate. This "non-contact" printing method is ideal for textiles. Secondly, inkjet is a very efficient method of printing, only applying ink where it is required with no waste from ribbons and other consumables used in competing digital printing technologies. Developments in recirculating printheads have enabled robust printing of pigmented inks which are required for darkly colored textiles. Tiling of printhead segments has enabled single pass printing, greatly enhancing printing speed and essential for any digital technology which hopes to compete with wide web rotary screen textile printing.

Reactive dye printing is in widespread use today. Jetting reactive dye-based inks is very reliable, requiring lower printer maintenance than pigmented ink solutions. However,

excess unreacted dye must be removed from the printed textile, creating a wastewater stream which must be managed.

Dye Sublimation printing was pioneered by Sawgrass in the early 1990's and opened up the field of digital textile printing. This highly successful technology is used for printing athletic wear, soft signage, interior decoration, skis & snowboards, coffee mugs and so much more. While this printing technology is limited to white or light-colored synthetics, the dense blacks & chromatic colors which can be produced offer state of the art color gamut and outstanding interior durability.

Direct to Garment (DTG) printing was developed as a digital alternative to screen printing onto dark colored t-shirs and other apparel. Several innovations in ink materials, chemistry and formulation were required to enable the successful development of this technology.

1. First, highly stable nano-particle pigment dispersions were required to replace dye-based colorants. Pigments are widely used in analog screen inks. However, inkjet-able pigment dispersions are much more difficult to develop. Innovations in pigment dispersion technology as well as dispersion making processes were key enablers here.
2. Inkjet-able textile resins to anchor the pigments to the textile fibers was another key enabler. Such resins are widely used in screen printing inks which accommodate high viscosity and resin concentrations. Inkjet ink on the other hand must be low in viscosity to be compatible with inkjet printhead technology. These resins are often based on anionic polyurethane dispersions with optimal mechanical properties for a "soft hand" on the printed textile as well as good wash and abrasion durability. Compatibility between the pigment dispersions and the textile resins is a significant challenge and remains an opportunity for further innovation.
3. Jet-able super-opaque white inks are required for printing onto dark textiles, particularly in the t-shirt printing business. Again, innovations in dispersion technology and pigment milling are key enablers here.
4. Inkjet printheads able to accommodate the large particle size of white, titanium dioxide pigmented inks were required before the DTG process could see the light of day.
5. Finally, cationic textile pretreatment formulations needed to be developed to prevent the pigmented inkjet ink from penetrating deeply into the textile. Unlike dye-based inks which color the textile fibers and are transparent. Pigment based inks are reflective. Pigmented inks must remain on or close to the surface to reflect vibrant colors. When these inks penetrate deeply into a darkly colored textile, the textile fibers hide a good portion of the pigment, leading to muted colors. By treating

the surface of the textile with cationic salts, the anionic polyurethane dispersions in the ink can quickly react with these salts for rapid ink gelation, minimizing ink penetration into the textile. Pre-treatments can be applied in a separate process, outside and away from printer or inside the printer with great care to avoid gelling inks in the printheads. While pretreating textiles has been very successful, it remains a difficult to manage process with much inconsistency due to variations in the textiles themselves as well as pretreatment application process variability. These difficulties have limited the growth of DTG printing.

Direct to film technology (DTF) leverages much of the innovation developed for DTG printing but eliminates the need for textile pretreatment. DTF has the further advantage that it is compatible with numerous light and dark colored textiles. Rather than printing directly on the textile, images are printed onto smooth, ink receptive transfer films. These films add an additional consumable but are much easier to print on than textiles, greatly improving image quality and sharpness. White inks are printed in the final pass for transfer onto dark textiles. Because of the smoothness of the film, significantly less white ink is required, improving the economics of this process. Powdered textile adhesive is applied to the printed film and the image is dried before transferred to the textile. Roll to roll printing is often used in DTF printing, enabling a separate workflow for image transfer to the textile or garment. Heat presses are used to bond the image to the textile. These operations are very compatible with the workflow in screen print shops where DTF printing has been widely accepted.

Direct to Textile (DTT) printing will be the most likely digital successor to analog textile screen printing. However, the substitution requirements are enormous and challenging. Lower-cost inks are needed to compete with analog screen inks. These inks must be compatible with a broad range of textiles. Pre and post textile treatments are undesirable as they are not required for analog printing. Ink curing must be on par with rotary screen drying process capabilities. Wash fastness and rub resistance must be in line with industry standards and digital inks must be able to reproduce the color gamut and print quality of screen inks. No toxic residue in printed textile from the ink or curing process is acceptable. Numerous R&D initiatives are underway to achieve these requirements. Many of the necessary component technologies have been developed. However, a robust digital printing process is still some ways off. Inks need to be more robust to re-circulation, pigment dispersions need to be less expensive, innovations in resins, dispersions, pigments and curing technology will need to complement advances in printheads and printer technology. Finally, inks need to remain close to the textile surface for vibrant colors.

Printed textiles are one of the last remaining processes to make the leap from analog to digital. Textile printing is a multi-billion $ market with low digital penetration, consequently there is much interest in developing a digital technology substitution. The huge economic opportunities of such a substitution are stimulating intense research and development in this area. The environmental and sustainability advantages of a digital process offer further incentives for this substitution. A systems approach will be required for the successful development of inks and printers which can meet the demanding needs of textile printing. Materials innovation, formulation optimization and printing systems integration improvements will all be required before this bold goal can be achieved.