Digital Textile Printing In The Fashion Industry

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Abstract

Conventional textile screen printing processes have supported the fashion industry for centuries. With the advancement of digital technologies and the consumer purchase behavior shift to fast fashion and sustainable fashion methods, the industry's printing needs are evolving, and manufacturers of digital textile printing devices are innovating to meet this demand. An overview of digital textile printing technologies will be given.

As we re-emerge from the global pandemic of 2020, there is a significant growth prediction for the worldwide digital print textile market. Allied Market Research projects the value to quadruple to $8.8 billion by 2027. Research and Markets predicts a CAGR of 9.37% and estimates that the global digital textile printing market will reach $1.66 billion by 2026. The research paper will examine the technological advances in digital textile printing and the driving market forces influencing its growth momentum.

Factors impacting the expansion in digital textile printing include agility and speed to market, cost-effective production processes, near-shore production, local material sourcing, increased creative application opportunities such as photorealistic reproduction quality and sustainable initiatives. Even conventional screen printers retrofit their equipment to support increased demand and speed in the printed textile market.

With sustainability at the forefront of operations and corporate social responsibility, advancing digital textile printing methods point to more sustainable fashion production. A closer look at the environmental impact of digital textile printing methods will be explored to evaluate the promoted benefits.

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Introduction

In the last couple of years, digital textile printing improved print speed and achievable technology significantly. In this study, currently available digital textile printing technology will be reviewed. Digital textile printing is also a driver of fast fashion since the technology allows for the faster production of new fashion styles. The impact of fast fashion on the environment will also be discussed. The research will aim to answer the question: Is digital textile printing fueling fast fashion, or is it making it more sustainable?

Fast Fashion and the impact on the environment

Before going into detail on how fast fashion impacts the environment, it needs to be established what fast fashion is. Fast fashion targets young consumers looking for trendy and cheap clothing (Joung, 2014). Fast fashion is meant to be worn less than ten times before the clothes are thrown away. Some items are so cheaply made that they can only be worn once or twice. As Brewer (Brewer, 2019) states, fast fashion contributes 17 – 20% of the global industrial water pollution and 10% of the world's carbon emissions. In the US, 11.9 million tons of clothing and footwear were discarded in 2015. Of these 11.9 million tons, 8.2 million tons ended up in landfills. As Brewer further states, many large fashion companies have been accused of disposing of large quantities of new merchandise. Many fast fashion items are made from synthetic fibers such as polyester, rayon or nylon, which may take up to 200 years or more to decompose. The global textile industry consumes the majority of PET (better known as polyester) more than plastic bottles and other PET products. Since PET is in fiber form, it is a significant source of microfibers, contributing to 85% of human-made debris on ocean shorelines (Browne, 2011). Companies like Zara, H&M, Forever21, and TopShop revolutionized the fashion industry through rapid production and quick, efficient supply chains. These companies dramatically expanded the industries' carbon footprint and promoted a culture of waste. Some newer numbers on the fast fashion industry are available from Cary Sherburne at WhatTheyThink.com (Sherburne, 2021). According to Sherburne, H&M revealed that it had $4.3 billion of unsold clothes in 2018.

In 2019 the apparel industry was the second-largest consumer of the planet's water supply and the second-largest polluter behind the petroleum industry. Another source indicates that the apparel industry contributes more to global emissions than aviation and shipping (Erhun, Kraft and Wijnsma, 2021). According to Peters, Li and Lenzen, consumers increased their clothing consumption from 2000 to 2015 by 47% (Peters, Li and Lenzen, 2021).

Sherburne (2021) states that around 85% of all textiles thrown away in the US, roughly 13 million tons in 2017, are either dumped into landfills or burned. On average, an American citizen throws away 37 kg of clothes annually. Globally

92 million tons of textile waste is created each year, and by 2030 this amount is expected to increase to 134 million tons.

After reading all these facts, one wonders how the pandemic impacted the fast fashion industry. The COVID-19 pandemic forced the fashion industry to redefine its supply chains, reshoring some of its production, meaning that production is happening closer to the point of need.

There are also initiatives by the fashion industry to reduce its carbon footprint. At the COP26 in Glasgow in 2021, the UN Fashion Industry Charter for Climate Action agreed to reduce their Greenhouse Gas Emissions by 50% by 2030 (UN Fashion, 2021).

Advances in digital fabric printing are starting to impact the fashion industry. These trends are as follows:

- On-demand printing
- Development of more sustainable textiles
- The use and development of different inkjet inks for digital textile printing.

Digital textile printing is also a step toward making the textile industry more sustainable (Savastano, 2022). Digital textile printing works well with e-commerce platforms and allows the on-demand fabrication of garments. In the same article in InkWorld, it was mentioned that digital fabric printing with inkjet results in lower energy consumption, a reduction in water use and a significant waste reduction. Also, the VOC emissions are significantly reduced. In the article, one could also read that the COVID-19 pandemic has accelerated the growth of digital textile printing. It also needs to be pointed out that digital textile printing is only seven to eight percent of the total textiles printed (Savastano, 2022).

These trends will be highlighted in the following paragraphs of this paper.

Conventional fabric printing

Conventional fabric printing is a multi-step process that uses a lot of energy and water. Conventional fabric printing is quite often done using silkscreen or rotary silk screen printing. Also, the dyeing of fabrics uses many harsh chemicals, and unfixed dye needs to be washed out, resulting in large quantities of polluted water. Also, after printing the fabric, the newly printed fabric needs to be steamed, washed and stentered. Stentering is another word for the process of finishing fabric. During the stentering of freshly woven cloth, the fabric is stretched to remove any unwanted creases, the length and the width of the fabric are controlled, the fabric is dried, the shrinkage of the fabric is controlled, pigmented printed fabric is cured, and various chemical finishes are fixed.

Digital fabric printing technologies

In the last couple of years, some developments have taken place in digital fabric printing. New inks and new textiles for digital textile printing have been developed. These developments have sustainability written all over them to counteract the adverse effects that fast fashion has on the environment. Digital fabric printing allows for the on-demand production of textiles instead of producing thousands of clothing items and hoping they will be sold. Fabric production has also changed because only white, undyed fabric is produced for digital printing. Just this fact alone already reduces the environmental footprint of clothes manufacturing because the fabric dyeing process also creates a lot of pollution.

It needs to be pointed out that different types of inks are used or can be used depending on the type of fabric they are going on. In a 2018 article from Ding et al. (Ding et al., 2018), these are well described. They state that digitally printed textiles are often subject to pre- and post-treatment to improve their performance. Pretreatments include cationic modification, atmospheric pressure plasma, gas plasma and chemical padding. The following table is adapted from Ding et al.

Colorant	Substrate	Colorant-fiber interaction
Reactive	Cotton	Covalent bonding
Acid	Silk and Nylon	Electrostatic forces
Disperse	Polyester	Solid-solid solution
Pigment	All fibers	Surface bonding

Table 1: *Colorants used for different substrate types in textile inkjet printing after Ding et al. (Ding et al., 2018)*

Acid ink for digital textile printing

According to McKeegan (McKeegan, 2021a), acid inks for digital textile printing show outstanding color brilliance, lightfastness, and wash fastness. They are used to print high-quality top-end fashion on delicate silks, soft cashmeres, and colorful sports and swimwear. Acid inks can also be used on wool, nylon, and leather fabrics. Aquatic clothing is often made from a blend of Lycra and nylon fibers, and acid inks give color penetration on stretch fabrics and have a high tolerance for chlorine and salt water. Acid inks account only for 15 – 17% of printed textiles.

How are acid inks working?

The inks are dye-based. They are water-soluble acid dyes with added humectants, polymers, and surfactants. These added components control the flow, jetting and wetting behavior in the printhead and on the fabric. The humectant is there to control the drying at the printhead nozzle. Before jetting the acid dye-based inks onto the fabric, it must be pre-treated. The pre-treatment is often acrylate-based and contains a migration inhibitor. An important factor is controlling the pH level

reaction for fixation and limiting penetration, and sideways ink bleed across the fibers. This is a crucial factor for printing on silk fabric. After printing, the fabric must be steamed at 100 – 102ºC for 35 – 40 minutes. Next is a post-wash process to remove any unfixed dye and remaining pre-treatment chemicals. Several wash cycles will be needed to remove waste ink before the required performance of the fabric is obtained.

Dye-sublimation inks

Dye-sublimation inks can also be printed using inkjet technology, but they require a transfer sheet before the design is applied to the fabric. The design is printed onto the transfer sheet, and then heat and pressure are applied to transfer the dyes from the sheet onto the textile. Temperatures between 175 and 215ºC are used to transfer the dye onto the fabric. As the name of the inks implies, the dye converts from the solid phase to the gaseous phase. This conversion is called sublimation. The gaseous dye enters the fabric's pores, which results in nearly permanent, high-resolution prints on the fabric. This is because the dye is infused into the substrate at a molecular level and not on top of the fabric. Inkjet printers applying dye-sublimation inks use piezo-electric print heads. Dye sublimation is used for printing on polyester and polyester resin-coated products. Dye sublimation printing is used for home décor, soft signage, and sports apparel.

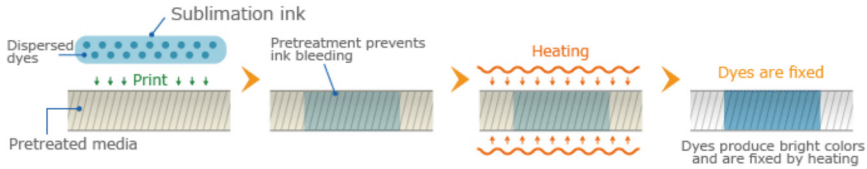

Figure 1: *Direct sublimation printing, printing directly on pre-treated fabric (Mimaki, 2022)*

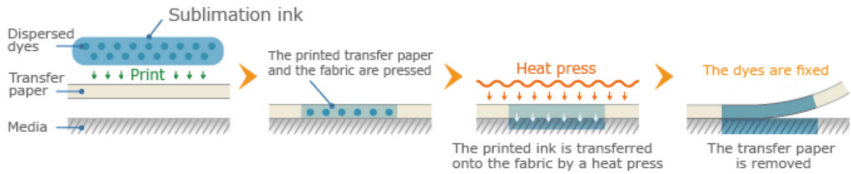

Figure 2: *Sublimation printing using a transfer paper (Mimaki, 2022)*

Pigmented inks

Pigmented inks are the key driver for the direct-to-garment (DTG) and direct-to-film (DTF) markets. DTG printing uses pigmented inkjet inks which can be applied to virtually any type of fabric. Pigment-printed fabrics do not need to be washed after print. They are heat set and ready for sale when they exit the heat tunnel (McKeegan, 2021b). Depending on the inkjet printer manufacturer for pigmented printing on fabric, a pretreatment unit is necessary. Quite often, these pretreatment units are in line with the digital print unit. These pretreatment units offer control over factors like color-gamut, wash-fastness, and hand feel (Bertini, 2021).

Latex-based inks

Latex-based inks are one of the latest developments for printing directly onto fabrics. They work well with any synthetic or natural fabric (Faulkner, 2021).

Sustainability aspects

Printing clothing textiles through conventional screen-printing methods or modern digital inkjet technology contributes to the ecological footprint, which is a person, company, or activity's effect on the environment. Which print technology is more sustainable? A systemic tool to aid in sustainability comparatives is to perform a life cycle assessment (LCA). An LCA is a method to evaluate the impacts across a product's life from raw material, manufacturing, distribution, use and disposal. Let's review LCA influences on digital textile printing to assess if it is less harmful to the environment than traditional methods across its life cycle phases.

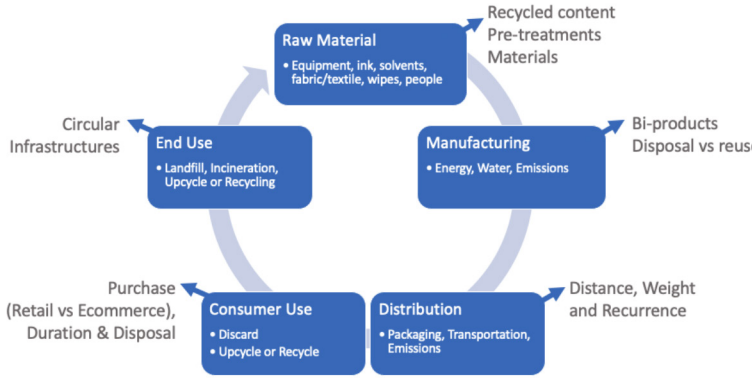

Figure 3: *Sustainability Life Cycle Phases of Textile Printing (Razik, 2023)*

The above cycle depicts the sustainability life cycle phases of textile printing and their potential inputs and outputs. When evaluating the sustainability impacts of a process and where to improve, it is unrealistic to consider a goal of zero effect. It is also expected that making sustainable shifts to one area of the life cycle may cause a trade-off to another area. Hence, it is vital to consider all the phases when evaluating environmental influences to understand their relational impacts.

In October 2020, Jos Notermans from SPG Prints evaluated the whole lifecycle of the textile printing process, comparing digital and conventional printing processes and subdividing the analysis into two phases.

1. From raw resources to manufacturing "cradle-to-gate."
2. From the usage phase of manufacturing to the end of the lifecycle, determined by the customer's actions "gate-to-grave."

Cradle-to-Gate: Sustainable Production

90% of the environmental footprint of textile printing is from raw materials and energy needed during the printing process, and 10% to wastewater and packaging (Notermans, 2020). The **production** of consumables was compared between producing one screen for rotary printing versus one kg of ink for digital textile printing. This was measured in Ecopoints, "used to index the environmental impact of products and processes" (Notermans, 2020). The rotary screen measured at 7 Ecopoints, whereby the digital ink scored at 0.3 Ecopoints.

SPG Print did not evaluate/compare digital print heads and rotary printing paste chemicals in their study. However, Debbie McKeegan of Texintel highlights that "the ink used in digital textile printing is typically 10% of the volume used in screen printing" (McKeegan, 2020). She continues to explain that physical color results are similar between pigment-based digital and conventional textile printing with digital using lower volumes of liquid dispersion. Maintaining colorfastness in digital printing processes is through heat fixation, whereby traditional fabric printing requires post-processing with steam and wash-off procedures, adding to the water and energy consumption.

Let's review energy and water comparisons. Digital textile printing "is typically 3.5% of screen printing's energy requirement" (McKeegan, 2020) and when printing on cotton, conventional processes use up to 60 liters of water per meter (70% more than digital print) and either release harsh dyes and chemicals into the water systems or are processed through expensive treatment facilities. Whereby digital printing methods do not require water use and, in turn, do not have the byproduct of noxious effluents discharged into local environments (McKeegan, 2020). Seven hundred sixty billion liters of water would be saved "if all linear meters in the world during one year were printed by digital textile printers instead of conventional printing" (Notermans, 2020).

Cradle-to-Grave: Impact of the End User

Consumers are the key driver of fast fashion and its popularity. As consumer needs shift and technologies such as AR and customization improve the front end of the purchasing process, the demand for agile manufacturing will also increase, making digital print technologies more enticing and cost-effective and reaping more sustainability benefits.

SGP Prints explains the difficulty of analyzing a comparative of sustainability influences across the whole lifecycle of textile printing because of the diversity of production variables. Yet it can be stated that an increased number of colors in textile designs will increase the number of rotary screens required to produce fabric

in conventional screen printing versus digital printing, impacting water, energy, and electricity usage (Notermans, 2020).

When digital printing processes are used to support textile manufacturing, high-level life cycle systems comparative analyses have highlighted 70% water savings, 55% energy savings, and lower VOC emissions inks in digital printing processes over that of conventional printing processes (Notermans, 2020).

Distribution, consumer use, and end of use are comparable environmental variables between print processes. Textiles, once printed, are **distributed** to local and international markets for sewing and finishing. **Consumers use** and wear fast fashion at a rapid pace of under ten times before it is discarded. The final life cycle phase is the **end of use**, whereby garments are put into landfill or incinerated.

Sustainability in Fashion Beyond Print

What is driving the fast fashion industry to more sustainable directions beyond print? Consumer behavior, global reform and regulations are the start engines. However, operational efficiency and versatility in restructuring the manufacturing supply chain in textiles have positive sustainability impacts. Production workflow automation and upstream software technologies for consumer shopping experiences, such as augmented reality and data mining, enable targeted purchasing to minimize waste, reduce inventory risk and stop overproduction. These, combined with digital print technologies, support the advancement of supply chain agility, environmental consideration, and lean manufacturing practices.

Latest Advancements

In her latest article, McKeegan (McKeegan, 2023) gave an update on the growth of the digital textile industry. According to Grand View Research, mentioned by McKeegan the market is expected to have a CAGR of 14.4% from 2023 to 2030. The precision of digital textile printing and web-based on-demand business models drives growth. Some web-based on-demand businesses are Printful, Cottonbee, Spoonflower and Merch by Amazon. These companies have minimal inventory, fast delivery and high-quality products. McKeegan further states that digital textile printing uses a fraction of the water, minimal energy, and a greatly reduced operational footprint compared to analog textile printing.

The digital workflow eliminates many laborious manual processes like making screens for rotary screen printing, cleaning them after use, storing them, mixing liters and liters of color-correct inks, etc.

According to a report by Research and Markets mentioned in McKeegan (2023) article, the digital ink sector for textile printing is expected to show a growth of

75%. The ink costs for digital textile printing are predicted to be reduced from 47.3% to 24.2% between 2020 and 2025. They also predict growth in digital ink consumption by 200% in the same period.

A report by Verified Market Research mentioned in the same article by McKeegan that the market for digital textile printing will double in size to over $470 million by 2027, yet is still only 5% of all printed textiles.

Digital textile printing hands the power back to the consumer by enabling on-demand printing, freeing them from mass production.

McKeegan (2023) also talks about sustainability in her article. She states that printing technology is evolving rapidly while the fabrics haven't changed much in the last 100 years, but new and more sustainable fibers are becoming mainstream. Most carbon emissions and release of toxic materials happen upstream from printing in the manufacturing of fibres.

Platforms like TextileGenesis are pioneering traceability from fiber to retail. Supply chain transparency has become a top priority. This platform is used in a pilot program with leading brands like H&M, ArmedAngels, Mara, Hoffman and Chicks.

Conclusions

Digital textile printing is evolving rapidly to meet the commercial demands of conventional textile printing to offer the industry manufacturing agility, sustainable alternatives, and supply chain operational efficiencies. The examples shared within this paper lean towards digital printing methods having a less environmental impact from cradle-to-grave than conventional rotary textile screen printing methods. It is a more costly technology meter for meter and measures only 5-7% of the global textile print market (McKeegan, 2020). With existing infrastructures in place, there is a barrier to change. Yet, with consumer behaviors voicing their shift to more sustainable choices, government regulations impacting operational requirements, and technological advancements becoming available, it may be a competitive disadvantage if traditional textile operations do not begin to evaluate the potential to restructure or hybrid their processes.

To answer the question from the beginning of this paper: Digital textile printing is/can fuel fast fashion but makes it more sustainable by requiring fewer resources through on-demand fabrication and the use of more sustainable fibers.

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