

ADVANCED TEXTILES MANUFACTURING INDUSTRY
Learning unit 3 Technologies for functional and smart textiles
Lesson 2

Resource efficient textile processes for functional and smart textiles: digital printing and spray technology



Innovative smart textiles & entrepreneurship

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RESOURCE EFFICIENT TEXTILE PROCESSES FOR FUNCTIONAL AND SMART TEXTILES: DIGITAL PRINTING AND SPRAY TECHNOLOGY

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Introduction

Resource efficient processes such as digital printing, 3D printing and spray technology are modern technologies that have revolutionised the textile industry. For example, digital inkjet printing offers many advantages over traditional textile printing methods. One of the most significant benefits of digital inkjet printing is its ability to save important resources such as water and energy compared to conventional manufacturing methods. Traditional textile printing processes, such as dipping, coating, and screen-printing, consume large amounts of water and energy, which results in high operational costs and environmental impacts. Inkjet printing process involves the precise deposition of ink onto the textile surface without any wastage or overspray, which results in significant resource savings.

Furthermore, digital inkjet printing also reduces the use of chemicals in the textile printing process. Traditional printing methods require the use of various chemicals, such as dyes, thickeners, and fixatives, which can be harmful to the environment and human health. On the other hand, digital inkjet printing uses water-based inks that are free from harmful chemicals, making it a safer and more environmentally friendly option.

In addition to resource savings, digital inkjet printing technology can also be used to functionalize textile surfaces with biomaterials, such as enzymes, for a range of advanced applications. Enzyme-functionalized textiles can be used for a variety of purposes, including antimicrobial, controlled release, drug delivery, quick detection, and bio sensing. The high precision and flexibility of digital inkjet printing make it an ideal technology for applying biomaterials onto textile surfaces.

Resource efficient processes are beneficial for ensuring precise, flexible, and contamination-free production. They are effective for small or custom-scale production quantities, which are not cost-effective using traditional textile dyeing and printing methods. These technologies allow for the production of high quality and customised textiles that meet the demands of modern-day consumers.

1. Digital inkjet printing

1.1. Introduction

The utilisation of digital inkjet printing technology in the advanced textile-manufacturing sector has opened up new possibilities. This technology is known for its resource efficiency as it consumes minimal materials and chemicals while producing very little waste during the process.

The flexibility it provides to the fashion sector plays a great role in adapting to the fast changing trends of the markets nowadays. High-resolution prints, endless colour choices, high-speed production and potential of industrialization with no minimum run length are few of the outstanding characteristics of this technology.

The designs are created digitally via software that are connected to the print heads, this allows a significant reduction of production time, as well as reduces storage space and costs related to the stamps/stencils used in rotary and screen printing methods.

1.2. Background

This technology has been popular since the 1970s, conducting printing directly from a digital-based image onto the textile. The technology ejects tiny drops of ink onto a substrate. In practice, the implementation of the technology is complex.

The technology is a resource-efficient process, uses the least amount of materials, water and energy. The colour model that is used in digital inkjet printing is CMYK. The time required in the printing process with its preparation is significantly shorter than conventional printing of textiles.

1.3. Main inkjet printing systems

There are main inkjet printing systems which are continuous and drop-on-demand. The focus in this lesson is drop-on-demand which mainly include thermal and piezoelectric printing systems. It is good to mention that the piezoelectric type has been used more than the thermal type. Because the thermal type has limited inks options due to the heat. In the thermal system the heat is used to force ink from the print head. The electrifying resistors behind the print nozzle, creating an intense heat that vaporises the ink to explode onto the substrate. On the other hand, in the piezoelectric systems, piezoelectric elements (crystals or ceramics) are built behind the nozzles. When there is a need to print a pixel, an electrical charge is applied, these elements force precise amounts of ink onto the substrate by pressure.

1.4. Characteristics and components of DIJ printing on textiles

Digital Inkjet (DIJ) printing on textiles is a printing technique that offers several distinct characteristics and components. One of its key features is the ability to handle variable data in a digital format, allowing for unrestricted size possibilities. This means that DIJ printing can accommodate different sizes of textiles without compromising the quality or resolution of the printed design.

In DIJ printing, there is no physical contact between the printing device and the textile substrate. Instead, ink is dropped onto the substrate using a non-contact method. This eliminates the risk of damaging the textile and allows for printing on various surfaces, including delicate or uneven fabrics.

The versatility of DIJ printing lies in its compatibility with different inks and substrates. This means that a wide range of inks can be used, including those suitable for natural or synthetic fibres. Consequently, DIJ printing can be applied to various textiles, such as cotton, polyester, silk, or even blends, offering flexibility in the choice of materials.

DIJ printing utilises the CMYK colour system, which stands for Cyan, Magenta, Yellow, and Key (Black). This system enables the creation of vibrant and realistic multicolor prints. By combining different proportions of these four colours, a broad spectrum of shades, hues, and gradients can be achieved, resulting in visually appealing and detailed designs.

One notable advantage of DIJ printing is the absence of moving parts in the printing process. This inherent reliability reduces the risk of mechanical failures and increases the overall durability of the printing equipment. As a result, DIJ printers are known for their consistent performance and prolonged lifespan.

In terms of speed, the printing rate of DIJ technology can vary depending on the resolution requirements. Higher resolutions may require more time for printing due to the increased level of detail. However, DIJ printing is generally considered to be a high-speed printing method, enabling efficient production and quick turnaround times for textile printing projects.

Digital inkjet printing comprises several main components that are crucial for the process and the quality of the prints produced.

Software: The software component plays a critical role in digital inkjet printing. It controls the entire printing process, including the input of the image or design to be printed. The software allows for adjustments such as image resizing, colour management, and positioning on the textile. It also provides control over other parameters like resolution and print speed. An efficient and user-friendly software interface is essential for achieving desired results in digital inkjet printing.

Textile: The textile used in digital inkjet printing is another vital component. It encompasses the material, structure, and texture of the fabric. Different textiles have varying characteristics that can affect the print quality, such as absorbency, smoothness, and elasticity. The choice of textile should be compatible with the printing process and ink chemistry to ensure optimal colour vibrancy, sharpness, and durability of the prints.

Ink: The ink used in digital inkjet printing is formulated to suit the specific textile being printed. The chemistry of the ink should be compatible with the textile's properties to achieve proper adhesion, colour penetration, and fastness. Inks designed for textiles often have properties like

water resistance, lightfastness, and washability to ensure the longevity of the prints. The ink composition, including pigment or dye concentration, viscosity, and drying properties, is carefully formulated to achieve desired printing results.

Printhead and Hardware: The printhead and hardware components of a digital inkjet printer are responsible for delivering the ink onto the textile. The printhead contains tiny nozzles that eject the ink drops onto the fabric's surface. It is essential to have a printhead and hardware that are compatible with the ink being used to ensure proper ink flow, drop size, and precise placement. The quality of the printhead and hardware can significantly impact the printing resolution, speed, and overall performance.

Compatibility between the components is crucial in digital inkjet printing to obtain good quality prints. The software needs to communicate effectively with the hardware and printhead, ensuring accurate control of ink deposition and positioning. The ink chemistry should be specifically formulated to match the textile being printed to achieve optimal color rendering and durability. Additionally, the textile structure and properties should be suitable for the printing process and ink absorption, allowing for vibrant prints. When all the components interact seamlessly, the result is high-quality prints with accurate colors, sharp details, and good wash and lightfastness.

1.5. Inkjet printing of Enzymes

In the field of textile functionalization, inkjet printing technology has shown promise for the application of complex materials such as enzymes. One example of this application is the inkjet printing of enzymes onto textiles to achieve bio-functionalization. This process involves using digital inkjet printers to deposit enzymes onto synthetic textiles, enhancing their properties and introducing new functionalities.

A study titled "Sequential Inkjet Printing of Lysozyme and Tyrosinase on Polyamide Fabric: Sustainable Enzyme Binding on Textile Surface," conducted by Biswas, Yu, and Nierstrasz in 2022 at University of Borås, explores the potential of inkjet printing enzymes on textiles. The researchers investigated the bio-functionalization of synthetic textiles through the sequential inkjet printing of enzymes, specifically lysozyme and tyrosinase, onto polyamide fabric.

One aspect of interest in the study was the antimicrobial activity of the printed fabrics. To evaluate this property, the growth of bacterial colonies on the fabrics was examined. In Figure 1, a red dot was used to represent the growth of a bacterial colony. The researchers observed that fabrics that were inkjet printed with enzymes exhibited a significantly lower number of bacterial colonies compared to fabrics without enzyme printing. This reduction in bacterial growth demonstrated the antibacterial efficacy of the inkjet-printed fabrics.

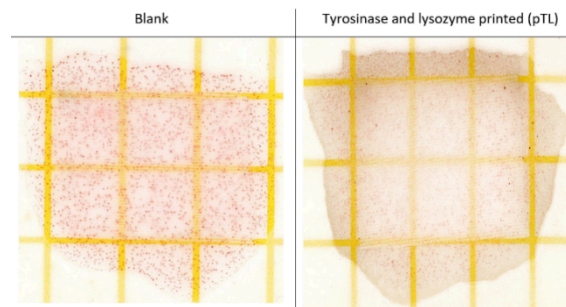


Figure 1. Bacterial growth on lysozyme and tyrosinase printed PA6,6 fabric

This study highlights the potential of inkjet printing technology for functionalizing textiles. By using inkjet printers to deposit enzymes onto fabrics, it becomes possible to introduce antimicrobial properties, among other functionalities, to the textile surface. This application has implications for various fields, including healthcare, where the antibacterial properties of textiles can be beneficial in preventing the spread of infections.

Want to learn more about this topic?

Blawie, T., Yu, J., & Nierströze, W. (2022). Sequential Inkjet Printing of Lysozyme and Tyrosinase on Polyamide Fabric: Sustainable Enzyme Binding on Textile Surface. *Advanced Materials Interfaces*, 9(22). doi: 10.1002/admi.202200723

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Tyler, D. J. (2005). Textile Digital Printing Technologies. *Textile Progress*, 37(4), 1-65. doi: 10.1533/text.2005.0004

2. Valve jet printing

2.1. Valve jet printing system

Valve jet printing is a type of inkjet printing technique that differs in terms of resolution and functionality. While inkjet printing typically offers higher resolution capabilities, valve jet printing is known for its lower resolution output.

In valve jet printing, which falls under the category of drop-on-demand technology, the printing process is initiated by an electromagnet that activates a plunger. The plunger is responsible for opening and closing the nozzle, allowing ink droplets to be ejected onto the substrate. Unlike traditional inkjet printers that can have a large number of nozzles, valve jet printing systems usually have a smaller number of nozzles and the drop size produced by this technique tends to be larger. Valve jet printing technology is often employed for printing on thick substrates, particularly in applications such as carpet printing.

Want to learn more about this topic?

Artur, C.-P., Nierstrasz, V., & Wang, Q. (Eds.). (2019). *Advances in Textile Biotechnology 2nd Edition*: Woodhead Publishing Ltd.

3. 3D printing on textiles

The world of 3D printing holds a wide range of technologies. At the highest level, there are three major categories for production of a 3D part including forming, subtractive or additive manufacturing (Figure 2). In the forming, the material will be reshaped. In subtractive methods as you can see in the figure, unwanted material will be removed from the 3D object with different methods like cutting or etching. In additive manufacturing, the 3D object will be formed by the layer-by-layer building process. The method begins with a 3D model designed with CAD software. This model then digitised and sliced into model layers with special software. Accordingly, 2D layers will be 3D printed into a 3D build.

The integration of 3D printing technology with textiles has sparked a new era of innovation in the field of textile manufacturing. This ground-breaking approach, known as 3D printing on textiles, combines the versatility of additive manufacturing with the flexibility and functionality of textiles, creating exciting possibilities for design, customization, and functional enhancements.

One of the key advantages of 3D printing on textiles is its ability to create customised and personalised designs. With the digital nature of 3D modelling and printing, intricate patterns, textures, and geometries can be easily translated onto textile surfaces, allowing for unparalleled levels of creativity and individualization. This technology empowers designers to bring their visions to life, transforming textiles into unique works of art and functional products.

Additionally, 3D printing on textiles enables the integration of functional elements directly into the fabric structure. For example, by incorporating conductive materials, sensors, or actuators, textiles can become interactive, responsive, and even "smart." This opens up possibilities for applications in wearable technology, healthcare, sports, and many other fields where textiles can play a transformative role.

Moreover, the combination of 3D printing with textiles offers significant benefits in terms of sustainability and material efficiency. By allowing for precise material placement and reducing waste, this technology contributes to more environmentally friendly manufacturing processes. It also enables the use of recycled or bio-based materials, further enhancing the sustainability profile of the printed textiles.

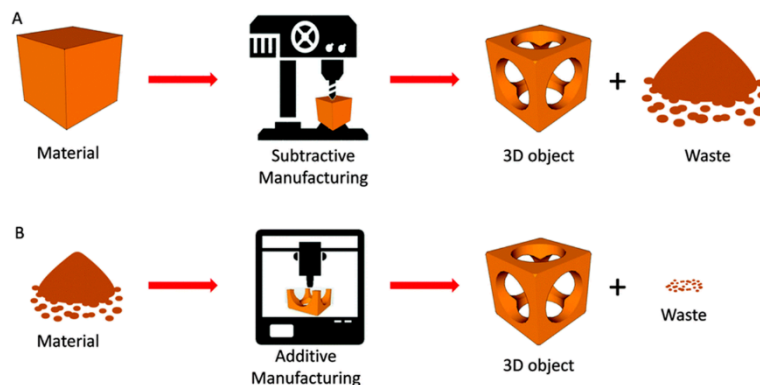


Figure 2. a) Subtractive Manufacturing b) Additive Manufacturing

3.1. Benefits and Challenges of 3D printing on textiles

3D printing on textiles offers a range of potential benefits in various applications where patterned, water-free, and solvent-free functionalization is required. This technology has the ability to improve the ecological footprint of textile manufacturing by minimising textile waste and reducing energy, water, and chemical consumption.

In addition to its environmental advantages, 3D printing on textiles is known for its high productivity, flexibility, and cost-effectiveness. The streamlined production process allows for efficient and rapid manufacturing, resulting in shorter time to market for textile innovations. This adaptability also enables quick response to changes in customer demands, ensuring a dynamic and customer-centric approach to textile production.

One of the most exciting aspects of 3D printing on textiles is its potential for developing innovative products in the realm of functional and smart textiles. By integrating sensors, actuators, and other intelligent components directly into the fabric structure, this technology enables the creation of textiles that possess enhanced functionalities and interactivity. This opens up possibilities for applications in wearable technology, healthcare, sports, and various other fields where intelligent textiles can make a significant impact.

3.2. Main challenges of 3D Printed Textiles

3D printed textiles present several challenges that need to be addressed to ensure their successful implementation in various applications. Some of the main challenges include durability, flexibility, and comfort.

Durability is a crucial aspect when it comes to 3D printed textiles. The printed structures must withstand the stresses and strains associated with regular use and maintain their integrity over time. Ensuring the durability of 3D printed textiles requires careful consideration of the materials used, the printing process parameters, and the structural design.

Flexibility is another important factor to address in 3D printed textiles. Textiles are expected to be pliable and able to conform to the body or other surfaces. Achieving the desired level of flexibility in 3D printed textiles requires finding the right balance between structural rigidity and flexibility, as well as optimising the printing parameters and materials.

Comfort is a key consideration in textile applications. 3D printed textiles should offer a comfortable wearing experience without causing irritation, stiffness, or restricting movement. Achieving optimal comfort involves understanding the interaction between the printed structure and the human body, as well as considering factors such as breathability and moisture management.

3.3. Affecting factors on 3D printed textile properties

Various factors affect the properties of 3D printed textiles, and they must be carefully addressed to ensure desired performance. Adhesion between layers and between fabric and printed layers is critical to maintain the structural integrity of the printed textile. Tensile properties, including strength and elasticity, determine the overall mechanical performance of the material. Bending and drape properties influence how well the textile can conform to different shapes and contours. Washability is crucial for maintaining cleanliness and longevity, requiring suitable materials and printing methods. Lastly, abrasion resistance is essential to ensure that the printed textile can withstand friction and wear without deteriorating.

Addressing these challenges and understanding the factors that influence the properties of 3D printed textiles are vital for advancing the technology and expanding its potential applications. Ongoing research and development efforts focus on improving durability, flexibility, comfort, adhesion, tensile properties, bending and drape properties, washability, and abrasion resistance to unlock the full potential of 3D printed textiles.

Want to learn more about this topic?

Ambrosi, A., & Pumera, M. (2016). 3D-printing technologies for electrochemical applications. *Chemical Society reviews*, 45 10, 2740-2755.

Hashemi Sanatgar, R. (2019). FDM 3D printing of conductive polymer nanocomposites : A novel process for functional and smart textiles. (Doctoral thesis, monograph), Högskolan i Borås, Borås. Retrieved from <http://urn.kb.se/resolve?urn=urn:nbn:se:hb:diva-21703> DIVA database.

4. Spray Technology

Textile dyeing is notorious for its wastefulness and has been questioned from a sustainability perspective. However, there is now a promising solution in the form of the Imogo Dye-Max spray dyeing line. This innovative development offers a sustainable alternative process that addresses the environmental concerns associated with traditional dyeing methods.

The implementation of the Dye-Max brings multiple benefits, not only for the environment but also for profitability and productivity. By utilising this technology, significant improvements can be achieved, including a drastic reduction in wastewater volumes, lowered energy and chemistry consumption, and increased production speed. Moreover, the consistent and predictable quality of the output further enhances its appeal.

In the Dye-Max process, the fabric passes through spray cassettes where a dye solution is sprayed onto the substrate. The combination of high-speed spray application and the unique Imogo autoclave fixation step enables a high output rate. This technology is suitable for a wide range of traditional dye classes and various fibre types, making it versatile and adaptable to different industry requirements.

The introduction of the Imogo Dye-Max spray dyeing line represents a significant step forward in the quest for sustainable textile dyeing practices. By adopting this innovative technology, manufacturers can reduce their environmental impact while simultaneously improving profitability and productivity. The combination of efficient spray application, autoclave fixation, and compatibility with diverse dye classes and fibre types makes the Dye-Max an appealing choice for those seeking a more sustainable and efficient approach to textile dyeing.

Want to learn more about this topic?

In [<https://imogotech.com/>] you will find more information about the spray technology.

Summary

Digital printing and spray technology are revolutionising textile printing and functionalization by offering resource-efficient processes with minimal water and chemical consumption and reduced waste production. These technologies address the limitations of conventional methods, providing numerous advantages such as faster production times, flexibility in design adaptation to changing fashion trends, and the development of innovative smart and functional textiles.

In digital printing, the elimination of metallic stencils reduces costs, time, and storage requirements, streamlining the printing process. This technology allows for endless design possibilities and customization.

The increasing interest in digital printing and spray technology stems from their significant potential in advanced textile manufacturing. They overcome many drawbacks of traditional printing and functionalization techniques, making them increasingly popular choices in the industry.

These resource-efficient technologies are driving the textile industry towards sustainability, efficiency, and enhanced product development; making them vital components of modern textile manufacturing.

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Daplyn, S., & Lin, L. (2003). Evaluation of pigmented ink formulations for jet printing onto textile fabrics. *Pigment & Resin Technology*, 32(5), 307-318. doi: 10.1108/03699420310497454

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