Digital inkjet printing in textile industry

Open Educational Resource developed by:

UNIVERSITY OF BORÅS

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Introduction

Digital inkjet printing technology offers new horizons to the advanced textile manufacturing sector, as it is a resource-efficient technology that consumes just enough materials and chemicals, with minimum waste production after 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. With high-resolution prints, endless color choices, along with high-speed production are few of the outstanding characteristics of this technology.

The designs are created digitally via software that are connected to the printheads, 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.
The drop-on-demand approach used nowadays in digital inkjet printing ensures the proper use of inks, with less hazards to operators and the surrounding environment due to reduced waste.

This technology revealed new possibilities in textile finishing as well, with more printhead options that are suited for temperature-sensitive inks, the functional inks can be applied to the textiles to add new functions, new properties, and even to produce sensors and smart textiles.

Keywords
Digital inkjet printing, Textile, Resource-efficient, Sustainability

Goals

Herein, we aim to provide a comprehensive yet summarized resource about digital inkjet technology to a wide variety of interested scholars with focus on main points such as: the basics of how digital inkjet printing systems work, with main focus on Drop-on-Demand (DOD) printheads. The difference in working mechanisms between thermal and piezoelectric printheads is discussed, along with the advantages and disadvantages of each mechanism.

Furthermore, the potential digital inkjet printing as resource-efficient technology in decorative or functional textiles is highlighted. Compared to conventional printing methods, different aspects and advantages are discussed to display the interest of this technology in modern-day and fast-changing textile industry.

One important goal of this resource is to introduce the different types of inks that are compatible with different types of textile materials such as wool, cotton, synthetic fabrics and silk. With emphasis on pre- and post-treatments required in each case to ensure a smooth printing process with high quality and durability.

Finally, few of the main applications of this technology in textile research and advanced manufacturing are summarized to highlight the potential of this technology in the future textile manufacturing.

Learning outcomes

This education resource was developed in efforts to facilitate and enrich the learning process of interested scholars in digital inkjet printing technology from different educational levels

The expected learning outcomes can be summarized:

- Understanding the printing mechanisms used in this technology.
- The main systems of machinery in markets nowadays (with focus on DOD printheads).
- Introduction to the main types of inks used on different textile material.
- How the digital inkjet printing differ from conventional printing on textiles.
- The main fields of application of this technology in textile research and industry

Structure

1. Background.
2. Main inkjet printing systems.
3. Characteristics and components of DIJ printing on textiles.
4. Textile as a substrate for digital inkjet printing
5. Main ink types
6. Digital inkjet vs. conventional printing
7. Environmental interest of digital inkjet printing
8. Pre-treatment, post-treatment and quality.
9. Applications.
10. Advantages and challenges.

1. Background

- It is a specialized form of reel-to-reel wide-format inkjet printing
- Conducting printing directly from a digital-based image onto the textile
- In theory, It is simple; A print head ejects tiny drops of ink onto a substrate
- In practice, implementation of the technology is complex
- It is resource-efficient process, uses the least amount of materials, water and energy
- The (CMYK) system of subtractive colors (cyan, magenta, yellow and black) is used in digital inkjet printing
- It has seen commercial success since the 1970s
- The time required in the whole printing process with its preparation is significantly shorter than conventional printing of textiles

1. Magdassi, Shlomo, ed. 2009. *The Chemistry of Inkjet Inks*. World Scientific. doi:https://doi.org/10.1142/6869

1. Background

Image: MIMAKI TX400-1800B

Digital image from software

Ink supply into the print head

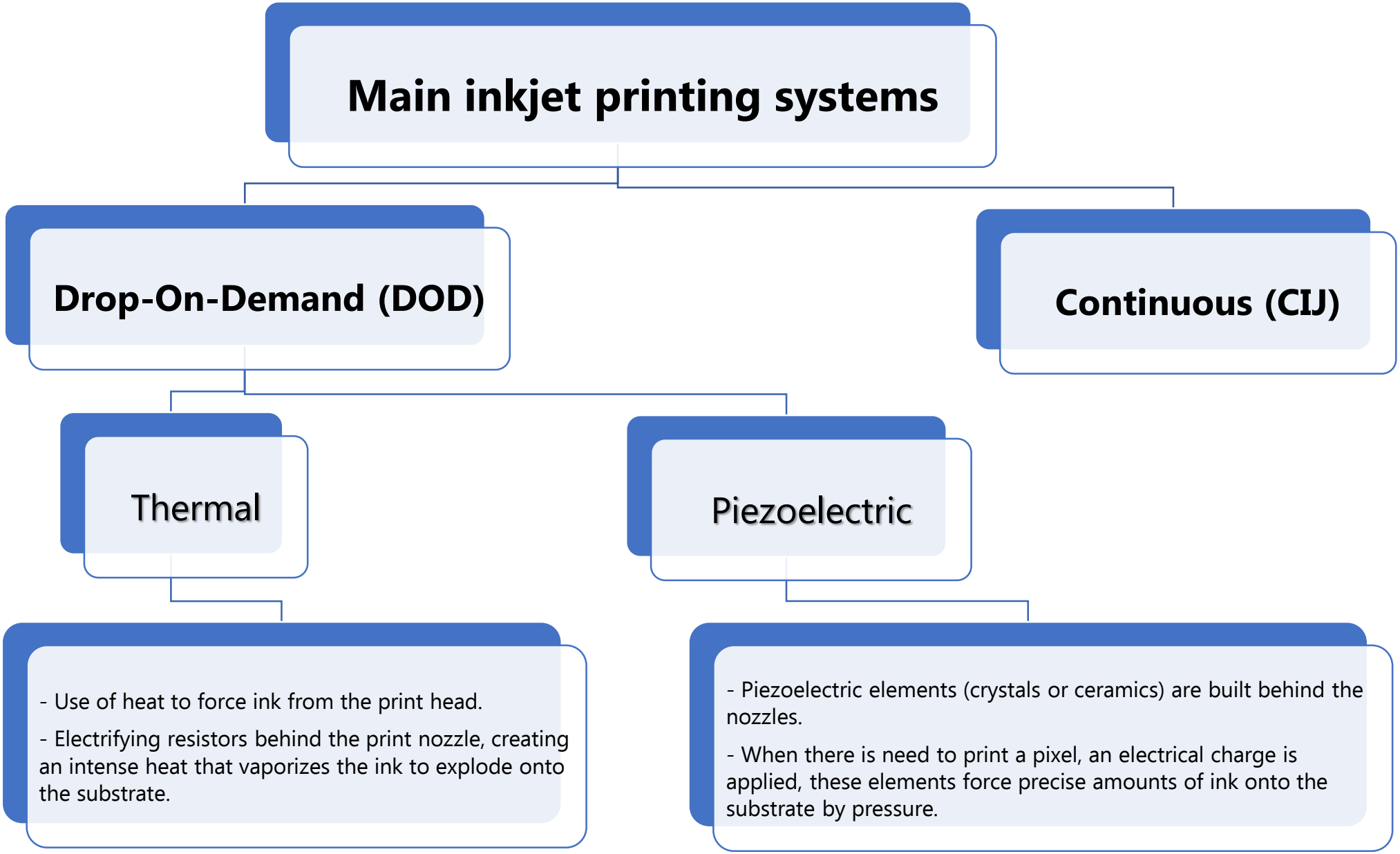
Printing on substrate

Post-treatment of substrate

Pre-treatment of substrate

2. https://www.signupdate.co.uk/Sign-News/mimaki-tx400-1800b

2. Main inkjet printing systems

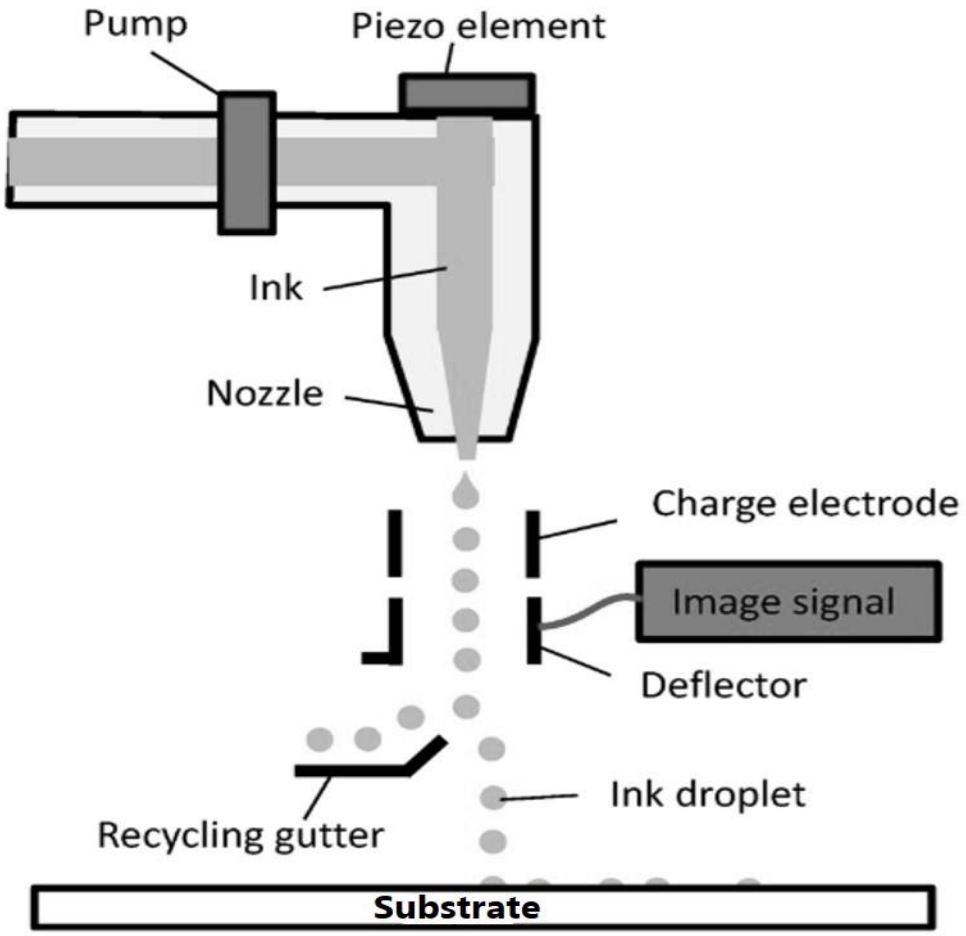


3. Tyler, David. J. 2005. "Textile Digital Printing Technologies." *Textile Progress* 37 (4). doi:https://doi.org/10.1533/tepr.2005.0004.
4. Daplyn, S, and L Lin. 2003. "Evaluation of Pigmented Ink Formulations for Jet Printing onto Textile Fabrics." *Pigment & Resin Technology* 32 (5). doi:https://doi.org/10.1108/03699420310497454.

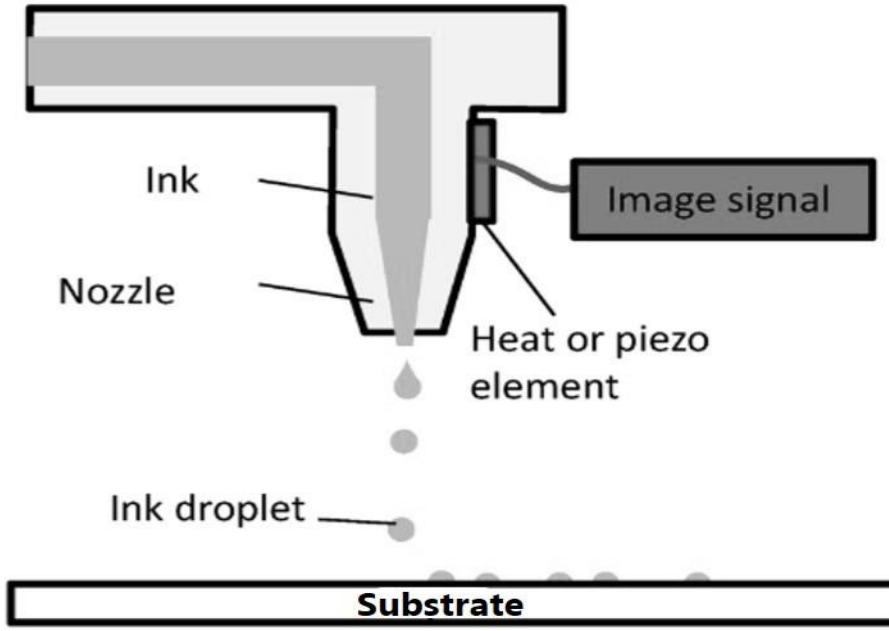
2. Main inkjet printing systems

There are other types of printheads, the ones mentioned are the main and most used overall

Continuous systems



Drop-on-demand systems

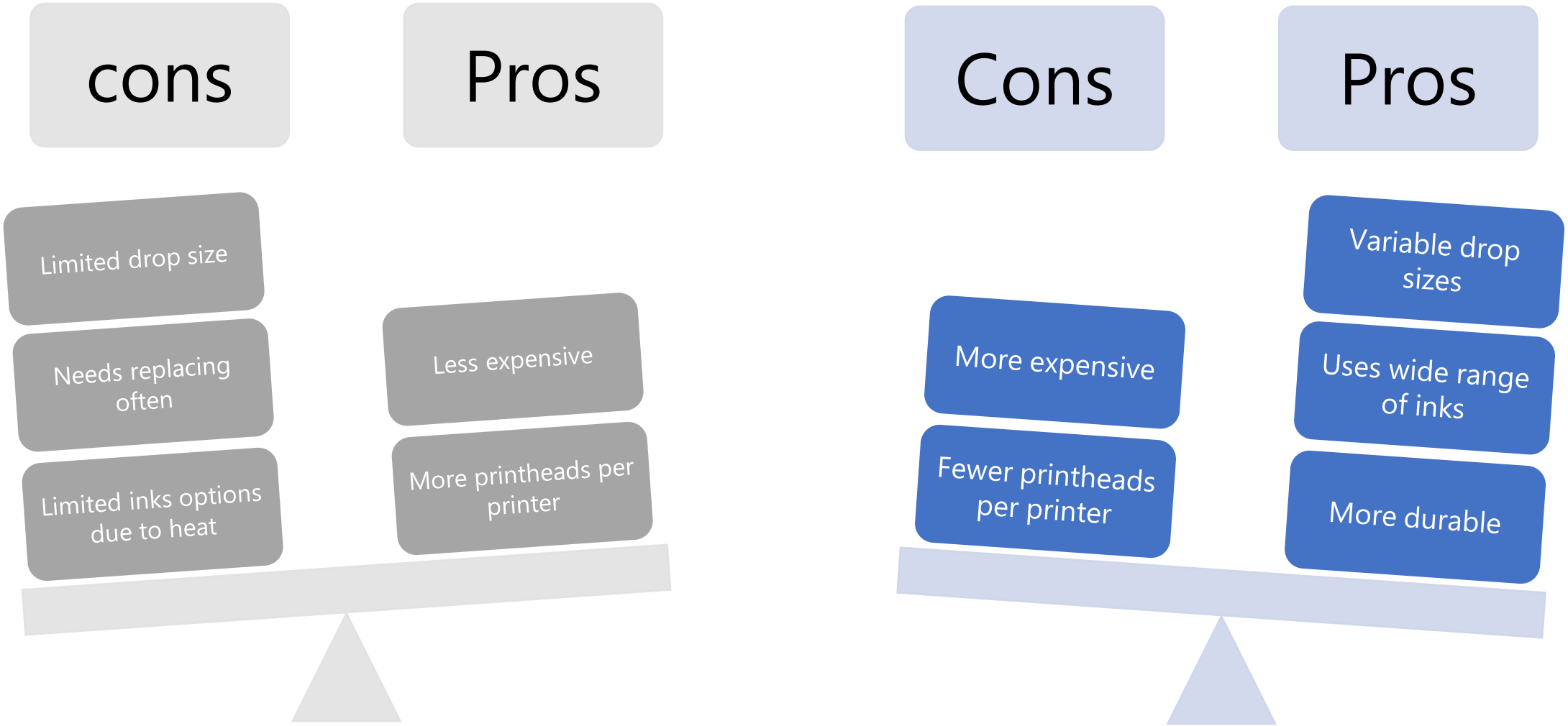


Reproduced from (Lau et al. 2017)

5. Lau, Gih Keong, and Milan Shrestha. 2017. "Ink-Jet Printing of Micro-Elelectro-Mechanical Systems (MEMS)." *Micromachines* 8 (6): 1–19. doi:10.3390/mi8060194.

2. Main inkjet printing systems

Drop-on-demand printheads



Thermal

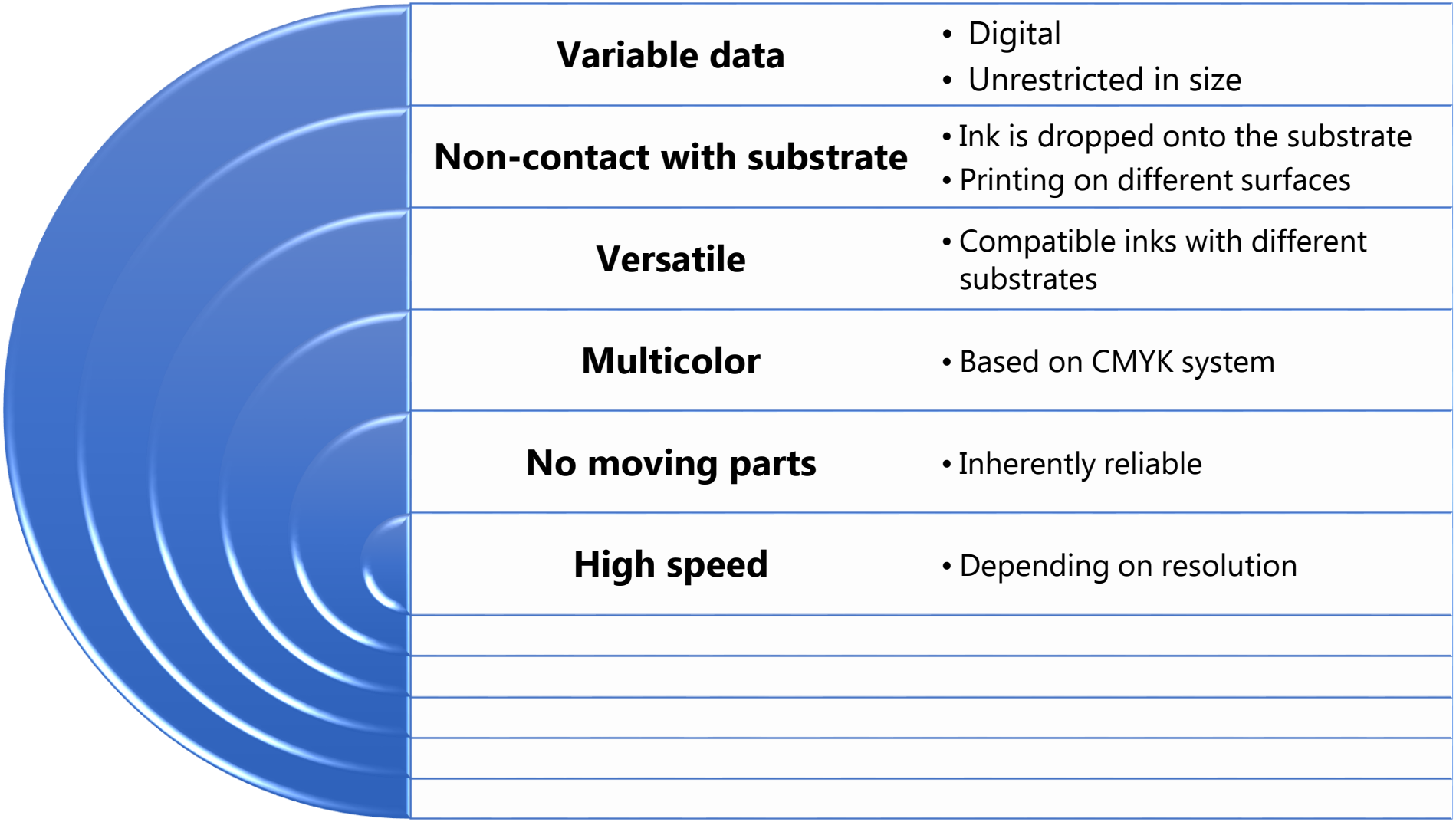
6. https://edgecolours.com/thermal-vs-piezo/

Piezoelectric

3. Characteristics and components of DIJ printing on textiles

Key characteristics of digital printing technologies

These main characteristics as defined by Keeling can be summarized



Variable data	• Digital • Unrestricted in size
Non-contact with substrate	• Ink is dropped onto the substrate • Printing on different surfaces
Versatile	• Compatible inks with different substrates
Multicolor	• Based on CMYK system
No moving parts	• Inherently reliable
High speed	• Depending on resolution

3. Tyler, David. J. 2005. "Textile Digital Printing Technologies." *Textile Progress* 37 (4). doi:https://doi.org/10.1533/tepr.2005.0004.

3. Characteristics and components of DIJ printing on textiles

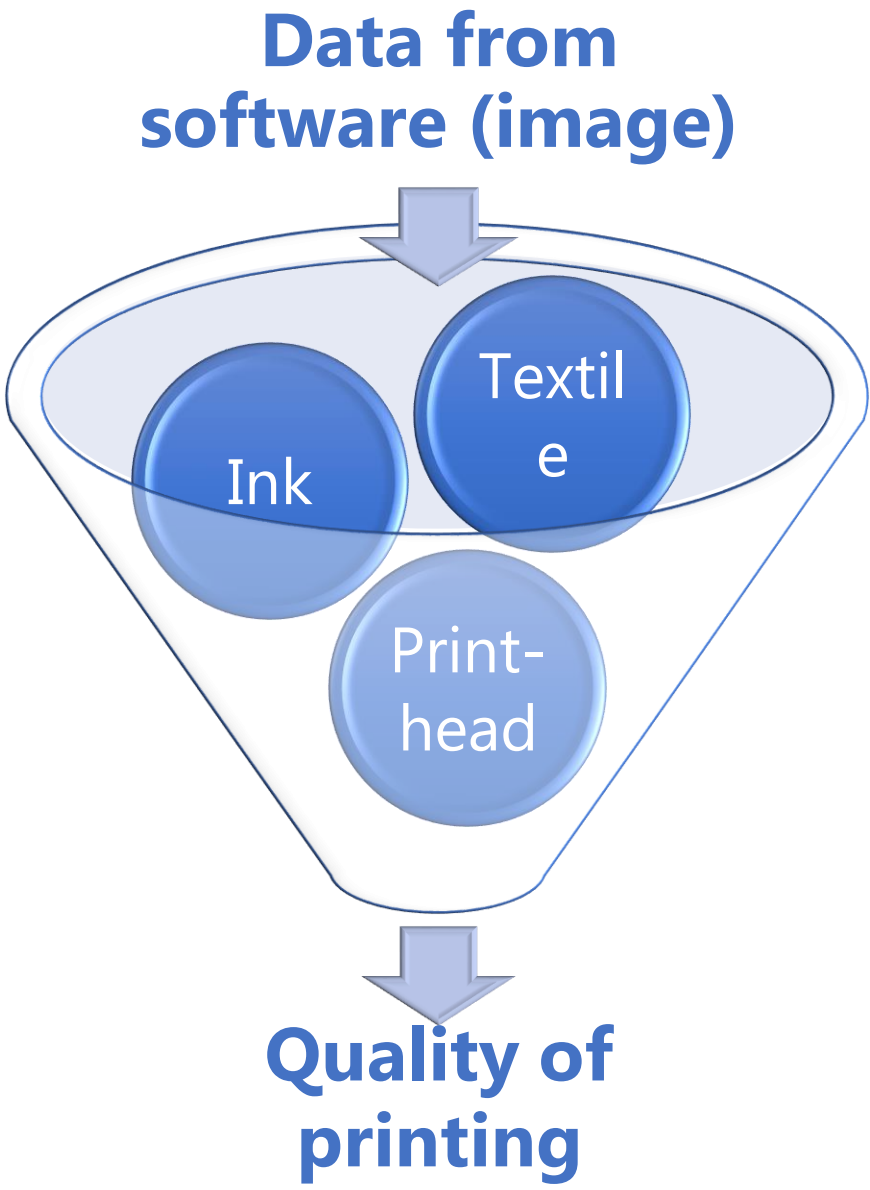
Main components of digital inkjet printing

- The main components of the printing process are:

1. The software (controlling process and input of image)
2. The textile used (material, structure, texture…)
3. The ink used (Chemistry to suit the textile used)
4. The printhead and hardware (compatible with the ink used)

- Compatibility in interactions between the components

  is crucial to obtain good quality prints



4. Textile as a substrate for digital inkjet printing

- Textiles possess some challenging characterizations when it comes to printing:

1. The texture of the surface differs according to the type and structure of textiles (woven, non-woven, knitted), and according to the type of yarns used (spun, multifilament)
2. The porosity and absorbency of textiles may cause some challenges
3. The ability to stretch, bend and the dimensional instability
4. The type of ink used is dependent on the material of textile to achieve bonding and adhesion (cotton, wool, synthetic…)
5. The need of specific pre- and post-treatment to obtain the best stability and quality of the prints (washing, bleaching, fixation, curing)

Image: printing on textiles can be challenging

5. Main ink types (according to the base used)

Type of ink	Post-printing treatment	Pros and cons
Water-based	Drying via evaporation	Environmentally friendly Affordable Needs lots of additives
Solvent-based	Drying via evaporation	Good image and durability Not environmentally friendly
UV-curable	Polymerization via UV curing	Fast curing Saves energy May cause harm if not cured properly
Hot melt	Solidification	Fast drying Adhesion might be poor

- The jettability of the ink is related to different factors such as the viscosity of the ink used, surface tension of the ink, its density, and the compatibility between the ink used and the print head used

1. Magdassi, Shlomo, ed. 2009. *The Chemistry of Inkjet Inks*. World Scientific. doi:https://doi.org/10.1142/6869.

5. Main ink types (according to colorant type)

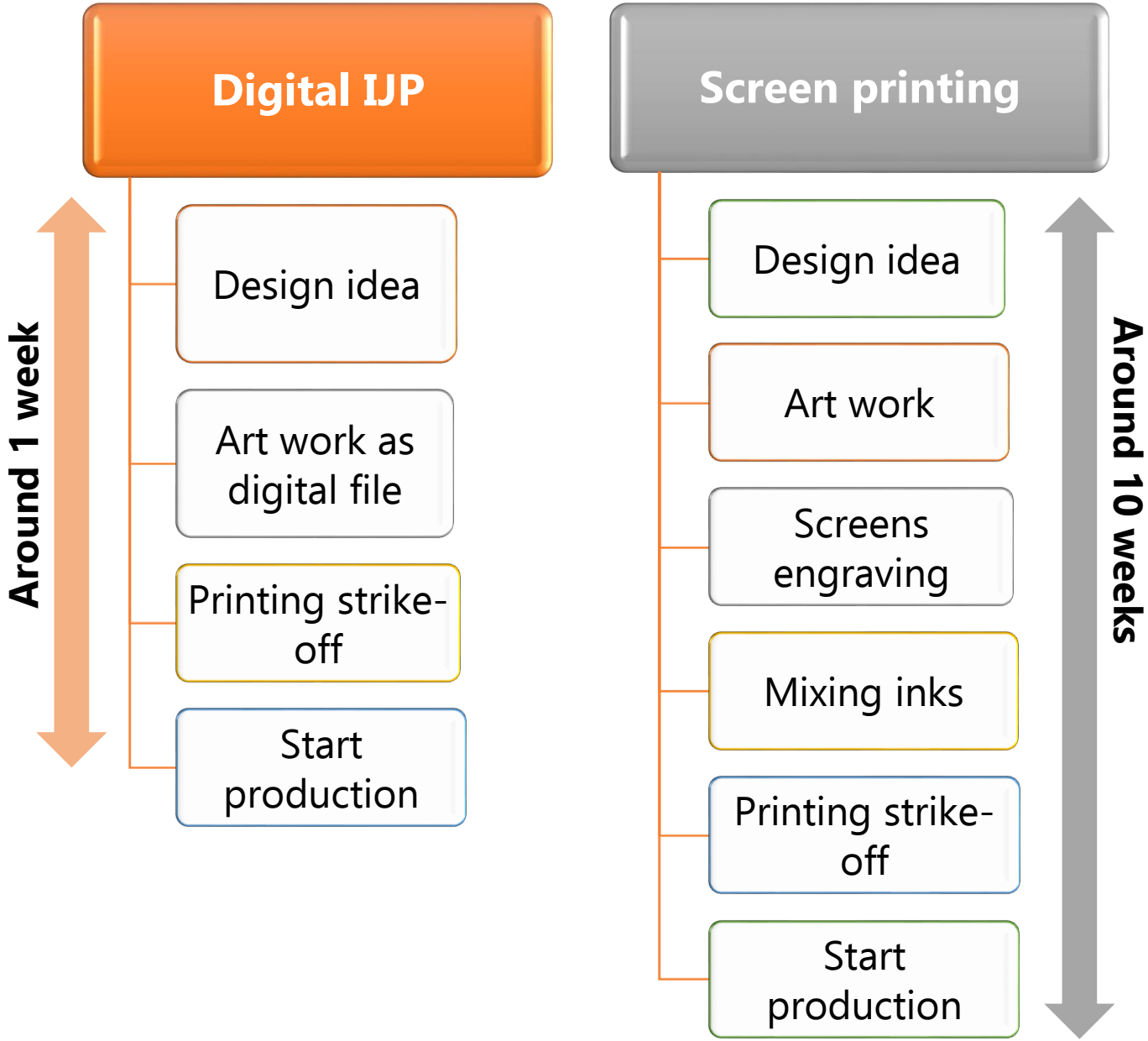
Type of ink	Type of fiber	Ink-fiber interaction	Main properties
Acid	Wool, silk, nylon, leather	Hydrogen bonds and electrostatic bonds	Good light, washing and rubbing fastness Bright colors
Reactive	Cotton, wool, silk, linen	Covalent bonds	Good washing and rubbing fastness Bright colors Poor light fastness
Dispersed	polyester	Hydrophobic-solid state	Good light, washing and rubbing fastness Bright colors
Pigment	All fibers	No interaction (depends on binder used)	Good light, washing fastness Bright colors Rubbing fastness depends on binder used
Sublimation	Polyester	Sublimation fixing via heat	High light, rubbing and color fastness

7. Tawiah, BENJAMIN, EBENEZER K. Howard, and BENJAMIN K. Asinyo. 2016. "The Chemistry of Inkjet Inks for Digital Textile Printing - Review." *International Journal of Management, Information Technology and Engineering* 4 (5): 61–78.

6. Digital inkjet vs. conventional printing

Cutting the time of preparation significantly

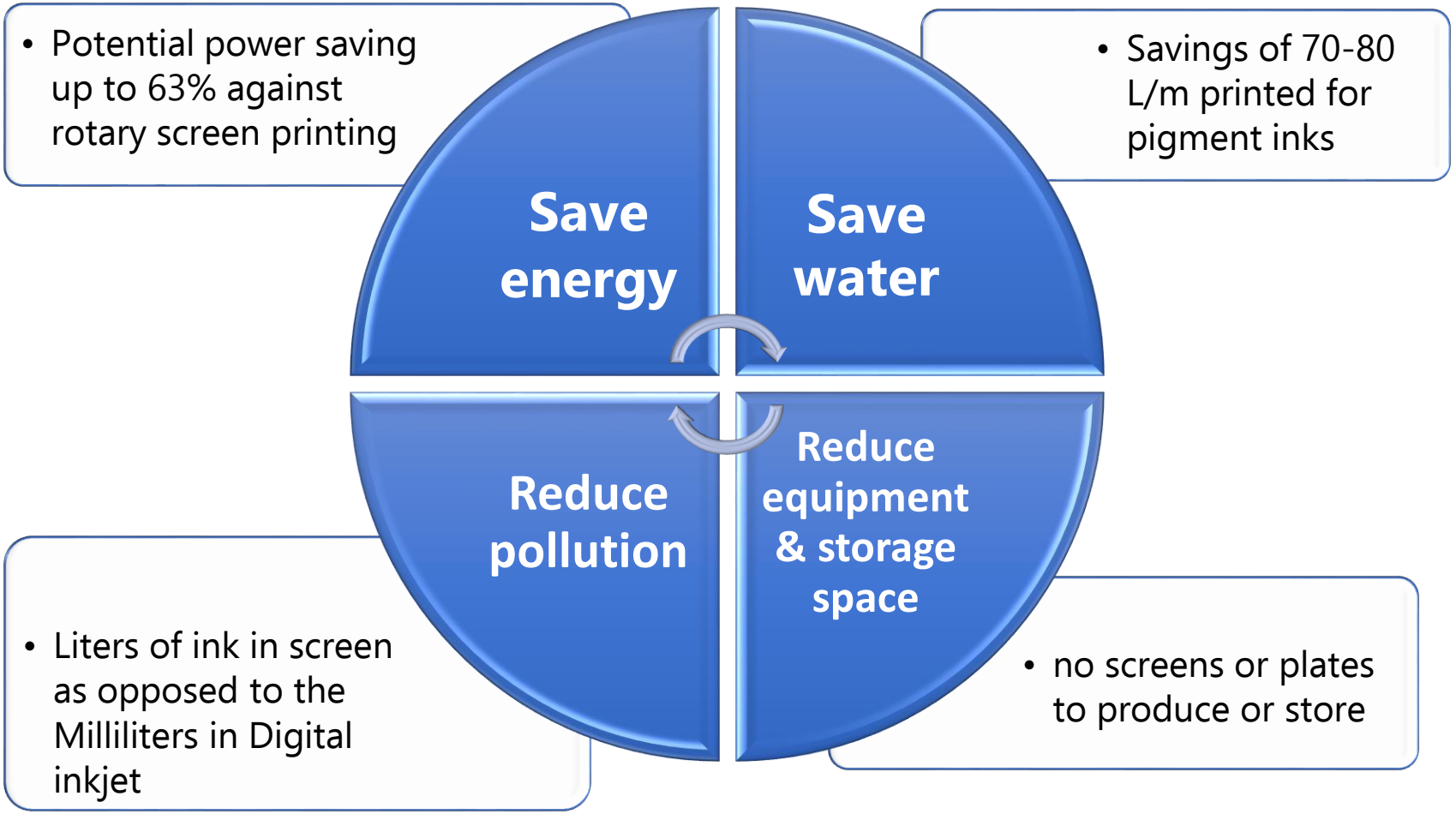
Sampling and proofing the patterns before actual bulk production is called STRIKE-OFF



8. Chandavarkar, Aditya. n.d. "Introduction to Digital Textile Printing." http://www.slideshare.net/adit_1285/introduction-to-digital-textile-printing.

7. Environmental interest of digital inkjet printing

- As digital inkjet printing technology has eliminated the step of stencil/stamp manufacturing, That resulted in reducing steps in the production, as well as allow for significant economical and environmental saving, with minimized storage space and waste production



9. Cie, Christina. 2015. *Ink Jet Textile Printing*. 1st ed. Woodhead Publishing. doi:https://doi.org/10.1016/C2013-0-16193-4. Department for Environment Food Rural Affairs/UK - DEFRA 2017

8. Pre-treatment, post-treatment and quality

Pre-treatments

- Pre-treatments are recommended according to the textile and the ink used, since the (**all-in** inks) may raise some difficulties during production:

1. Thickeners usually don't possess the required rheological properties
2. Chemical and solvents in the (all-in) ink cause corrosion of jet nozzle
3. Good for controlling ink penetration
4. Improving the printing resolution
5. Reducing bleeding
6. Some of the materials for specific pre-treatments are **urea, alkali or thickeners**
7. The textile should be well prepared before the pre-treatment (washing, desizing, bleaching…)

7. Tawiah, BENJAMIN, EBENEZER K. Howard, and BENJAMIN K. Asinyo. 2016. "The Chemistry of Inkjet Inks for Digital Textile Printing - Review." *International Journal of Management, Information Technology and Engineering* 4 (5): 61–78.

8. Pre-treatment, post-treatment and quality

Pre-treatments

Some of the materials used for specific pre-treatments prior to digital inkjet printing of textiles

Cotton and cellulosic fiber	Cotton prior to reactive	Silk prior to reactive	Polyester prior to disperse	Wool & silk prior to acid
• Thickener • Alkali	• Sodium alginate • Urea • Sodium carbonate	• Alginate • Urea • Lyoprint RG • Sodium bicarbonate	• Cibatex AR • Sodium alginate	• Gum • Urea • Ammonium tartrate

Image: Pre-treatment line

10. https://www.onlineclothingstudy.com/2018/03/digital-textile-printing-technology-and.html
11. https://textilelearner.blogspot.com/2011/03/pretreatment-of-textile-dyeing-printing_322.html

8. Pre-treatment, post-treatment and quality

Post-treatments

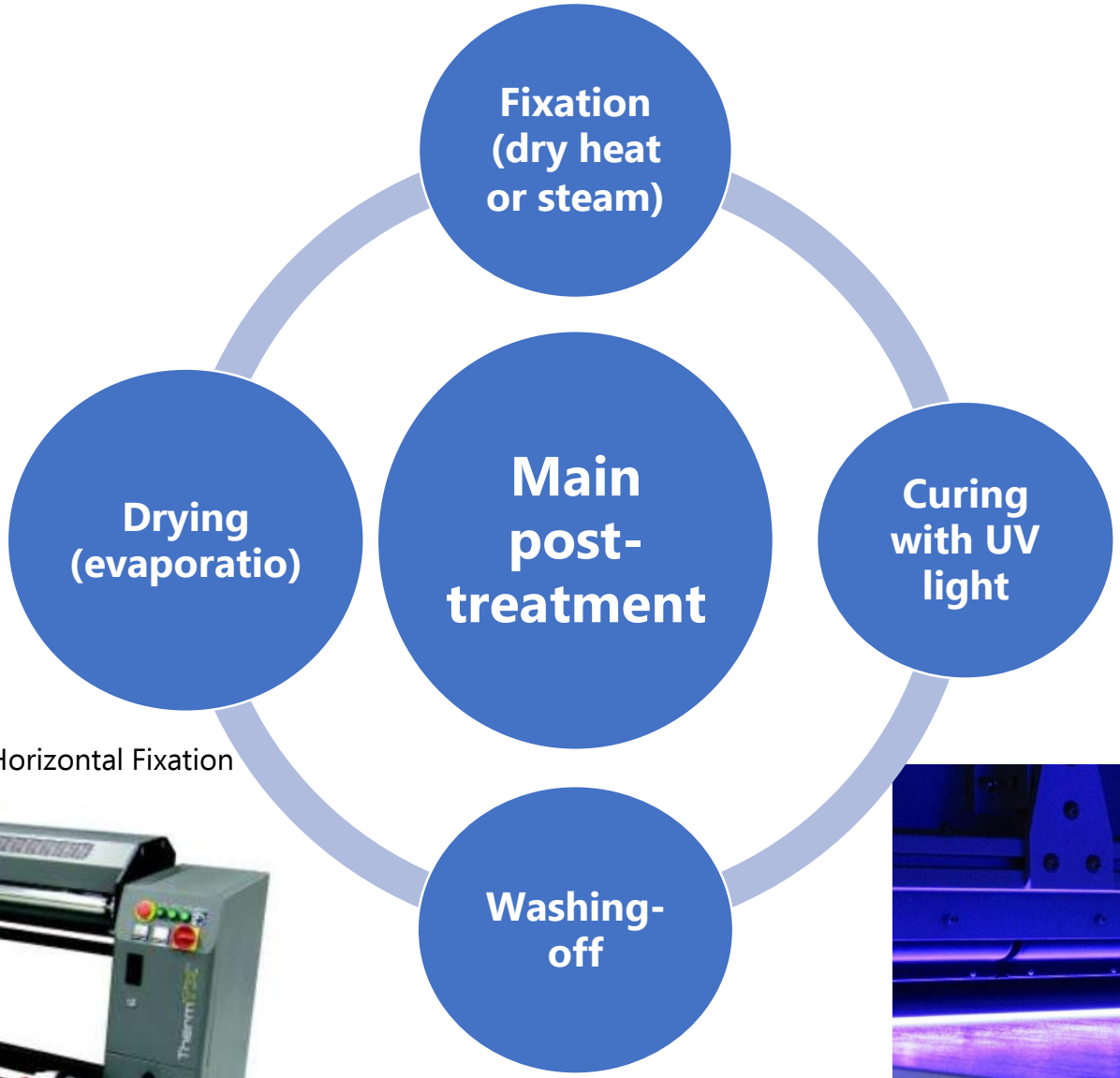
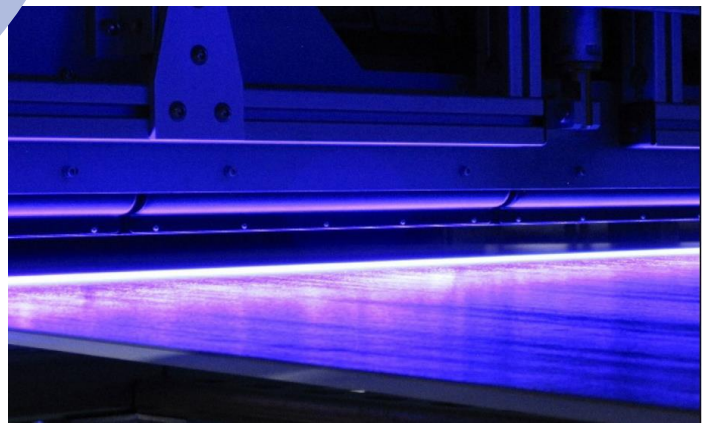


Image: ThermTX 75" FX and 102" FX Horizontal Fixation

Image: UV curing



12. https://uvebtech.com/articles/2019/state-of-uv-led-curing-applications/
13. https://www.perfectcolours.com/finishing/thermal-fixation-solutions/therm-tx/thermtx-75-fx-and-102-fx-horizontal-fixation.html

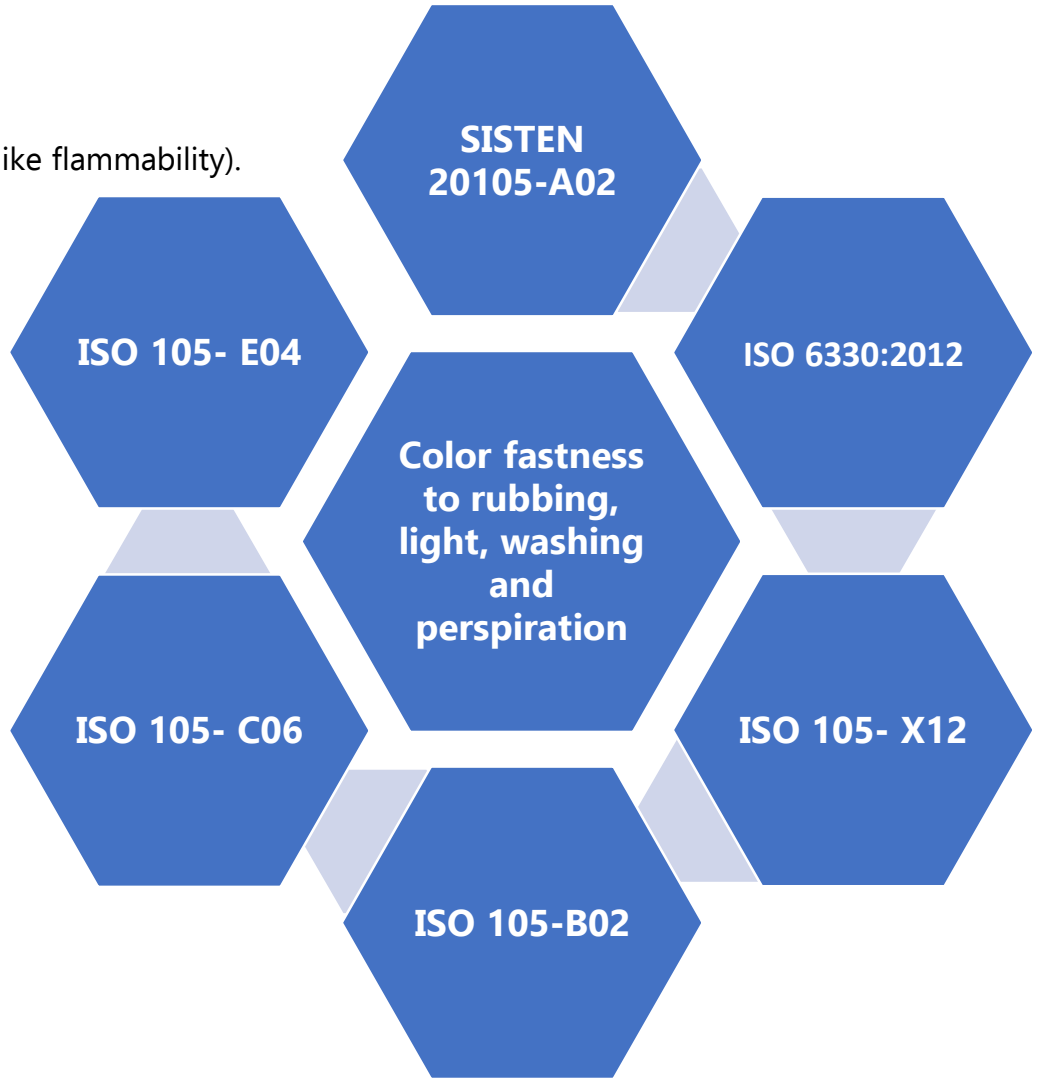
8. Pre-treatment, post-treatment and quality

Quality and durability testing of DIJ printed textile

- There are no mandatory legal requirements for color fastness testing (Unlike flammability).
- Color fastness testing is essential for customer satisfaction
- There are many standards for testing some of which are mentioned, including grey scale visual tests and ISO-family standards
- Key factors which contribute to color fastness:

1. Washing
2. Dry cleaning
3. Bleaching
4. Ironing
5. Rubbing
6. Exercising
7. Sun exposure

- Other important tests are light and rubbing fastness



14. Kašiković, Nemanja, Gojko Vladić, Neda Milić, Dragoljub Novaković, Rastko Milošević, and Sandra Dedijer. 2018. "Colour Fastness to Washing of Multi-Layered Digital Prints on Textile Materials." *Journal of the National Science Foundation of Sri Lanka* 46 (3): 381–91. doi:10.4038/jnsfsr.v46i3.8489.
15. Sahin, U. K., and H. Acikgoz Tufan. 2018. "Effects of Binder Solution on Color Fastness of Digital Printed Cotton Fabric." *IOP Conference Series: Materials Science and Engineering* 460 (1). doi:10.1088/1757-899X/460/1/012038.https://www.iso.org/standard/65207.html

9. Applications of digital inkjet printing on textiles

1. Fashion and domestic textiles

Image: Printed carpets

Image: Furniture and beddings

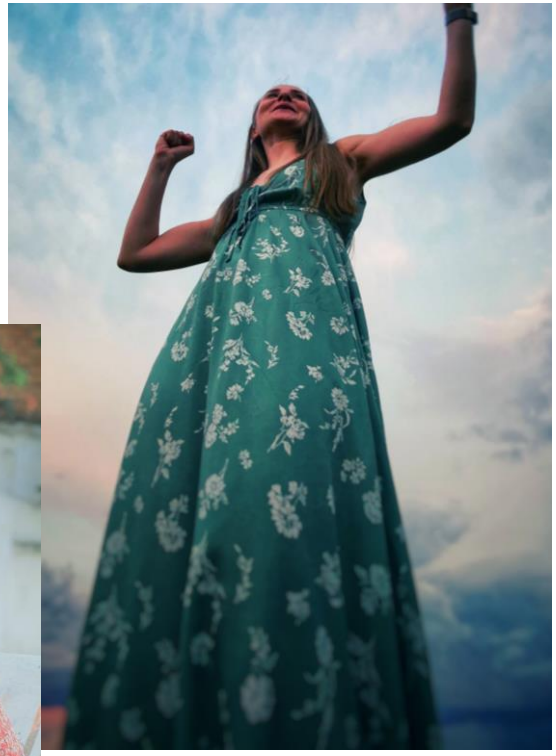


Image: Apparel industry

16. https://unsplash.com/

9. Applications of digital inkjet printing on textiles

2. Industrial and sportive printed textiles

Image: Entertainment and activities

Image: Flags

Image: Sports equipment and apparel

Image: Banners

16. https://unsplash.com/

9. Applications of digital inkjet printing on textiles

3. Functional and smart printed textiles

- Printed electrically conductive structures (such as the use of mixed metal nanoparticles, conductive polymer nanoparticles, and organometallic inks)
- Printed silver electrodes on textiles, applications in textronic systems, e.g., capacitors, textile heating actuators, textile antennas, and high-frequency transmission lines)
- Printed bioactive materials such as enzymes for applications related to biosensing in medical, pharmaceutical and sportive fields
- Durable water repellency (DWR) function on textiles
- Printed textile sensors and multicolored systems based on photochromic dyes

Image: Electrically conductive inks

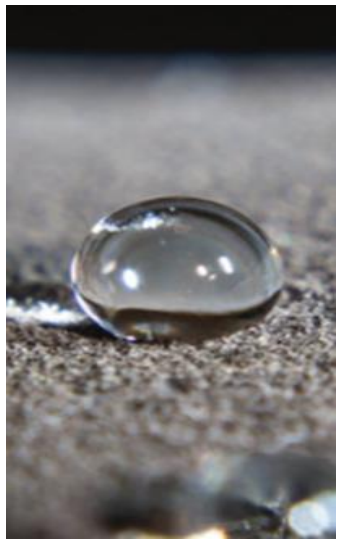


Image: DWR function

17. Stempien, Z., E. Rybicki, T. Rybicki, and J. Lesnikowski. 2015. "Inkjet-Printing Deposition of Silver Electro-Conductive Layers on Textile Substrates at Low Sintering Temperature by Using an Aqueous Silver Ions-Containing Ink for Textronic Applications." *Sensors and Actuators, B: Chemical* 224. Elsevier B.V.: 714–25. doi:10.1016/j.snb.2015.10.074.
18. Biswas, Tuser T., Junchun Yu, and Vincent A. Nierstrasz. 2019. "Effects of Ink Characteristics and Piezo-Electric Inkjetting Parameters on Lysozyme Activity." *Scientific Reports* 9 (1): 1–11. doi:10.1038/s41598-019-54723-9.
19. Yu, Junchun, Sina Seipel, and Vincent A. Nierstrasz. 2018. "Digital Inkjet Functionalization of Water-Repellent Textile for Smart Textile Application." *Journal of Materials Science* 53 (18). Springer US: 13216–29. doi:10.1007/s10853-018-2521-z.
20. Seipel, Sina, Junchun Yu, Martina Viková, Michal Vik, Marie Koldinská, Antonín Havelka, and Vincent A Nierstrasz. 2019. "Color Performance , Durability and Handle of Inkjet-Printed and UV-Cured Photochromic Textiles for Multi-Colored Applications" 20 (7): 1424–35. doi:10.1007/s12221-019-1039-6.

10. Advantages and challenges facing DIJ printing for textiles

Resource-efficient

Less waste

Freedom in designs

Fast change in patterns

Reduction of production time

High resolution prints

Ink development challenges

Blocked nozzles

Higher speeds are required

The need for pre- and post- treatments in some cases

21. Dehghani, A., F. Jahanshah, D. Borman, K. Dennis, and J. Wang. 2004. *Design and Engineering Challenges for Digital Ink-Jet Printing on Textiles. International Journal of Clothing Science and Technology.* Vol. 16. doi:10.1108/09556220410520531.

Conclusions

- Digital inkjet printing is a resource-efficient technology for textile printing and functionalization with minimum consumption of water and chemicals, and minimum waste production.
- This technology overcomes many disadvantages of the conventional methods of textile printing with reduction of time and endless flexibility of designs to adopt to the changing fashion trends, and developing innovative smart and functional textiles.
- The elimination of metallic stencils used in conventional printing process reduces cost, time and storage needed in the printing process.
- High-resolution printed fabrics from all types of materials can be produced via this technology, as well as integration of new functions on the printed textiles such as water repellency, in addition to printed electronics and biosensors.
- Compatibility between, fabrics, inks and printheads is a crucial condition for a successful printing process.
- It is recommended in some cases to conduct a pre- and/or post treatment for the printed textiles to ensure better durability and quality.
- The interest in this technology is rapidly increasing due to its great potential in advanced textile manufacturing, and its capacity of overcoming many disadvantages of conventional printing techniques.

Visit http://destexproject.eu/ to see the rest of the intellectual outputs of the project

Acknowledgement:
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