3D printed thermoplastic polymer screen for textile printing

3D tiskana šablona za tekstilni tisak upotrebom termoplastičnog polimera

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Abstract

This study investigate the application of 3D printing technology in the design of textile printing screens using a thermoplastic polyurethane polymer (TPU, trade name Filaflex Gold), known for its flexibility, durability and adhesion properties. These properties make it suitable for the production of reusable screens that meet the requirements of modern textile printing. The process involves designing the printing screen using CAD software's, preparing the file for 3D printing and optimizing parameters such as extruder temperature (215 – 250 °C) and printing speed. Using a 3D printer equipped for flexible filaments ensures accurate and reliable results. TPU printing screens are compatible with techniques such as screen-printing and hand painting. Thanks to their elasticity, they adapt to curved or irregular surfaces such as textiles, while their durability ensures multiple uses with minimal wear and tear. The method is cost-effective, sustainable and easy to implement on a range of production scales, from small workshops to industrial applications. This approach demonstrates the potential of combining 3D printing and advanced polymers to improve customization, reduce waste and increase efficiency in the design and manufacture of textiles.

Keywords: 3D printing; printing screen; thermoplastic polyurethane polymer (TPU); sustainable design

Sažetak

Ovo istraživanje proučava primjenu tehnologije 3D tiska u dizajnu šablone za tisak tekstila koristeći termoplastični poliuretanski polimer (TPU, Filaflex Gold), poznat po svojoj fleksibilnosti, izdržljivosti i svojstvima prianjanja. Ova svojstva čine ga prikladnim za proizvodnju višekratno upotrebljivih šablona koje zadovoljavaju zahtjeve modernog tiska na tekstilu. Proces uključuje dizajniranje šablone za tisak pomoću CAD softvera, pripremu datoteke za 3D tisak i optimizaciju parametara poput temperature ekstrudera (215 – 250 °C) i brzine tiska. Korištenje 3D printera opremljenog za fleksibilne filamente osigurava točne i pouzdane rezultate. TPU šablone za tisak kompatibilna su s tehnikama poput sitotiska i ručnog slikanja. Zahvaljujući svojoj elastičnosti, prilagođavaju se zakrivljenim ili nepravilnim površinama poput tekstila, dok njihova izdržljivost omogućuje višestruku upotrebu uz minimalno trošenje. Metoda je isplativa, održiva i jednostavna za primjenu na različitim razinama proizvodnje, od malih radionica do industrijskih primjena. Ovaj pristup pokazuje potencijal kombiniranja 3D tiska i naprednih polimera za poboljšanje prilagodbe, smanjenje otpada i povećanje učinkovitosti u dizajnu i proizvodnji tekstila.

Ključne riječi: 3D tisak; šablona za tisak; termoplastični poliuretanski polimer (TPU); održivi dizajn

1. Introduction

The development of 3D printing has revolutionized traditional manufacturing processes, offering unprecedented opportunities to produce intricate geometries with precision, efficiency and customization. 3D printing, which began in the 1980s with technologies such as stereolithography (SLA) and fused deposition modelling (FDM), has become a cornerstone of innovation in industries such as healthcare, automotive, aerospace and textiles. The adaptability of additive manufacturing has made it a driving force in advancing design capabilities and promoting sustainable manufacturing practices, making it a key enabler for the next industrial revolution [1-5].

In the textile sector, 3D printing has opened up new possibilities, such as the production of reusable printing screens for the decoration and customization of textiles. These printing screens, which are made from advanced thermoplastic polyurethane (TPU) materials such as Filaflex Gold, are characterized by exceptional durability, flexibility and mechanical strength. The elasticity of TPU ensures reusability, while the excellent adhesion to textile surfaces supports the production of high quality, intricate patterns. The unique combination of hard and soft segments gives TPU its special properties. The hard segments form physical cross-links that provide strength and heat resistance, while the soft segments give TPU its flexibility and resilience. This combination makes TPU strong and durable while remaining flexible. This innovation enhances both the aesthetic and functional aspects of textile products

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and paves the way for new creative and industrial applications. In addition, the adaptability of 3D printing enables rapid prototyping and on-demand customization, significantly reducing the lead times and costs associated with traditional methods of screen printing production [6, 7].
In addition to textiles, 3D printed screens have proven their usefulness in various other sectors. In the packaging industry, they facilitate embossing, labelling and decorative applications and enhance product presentation. In the ceramics industry, they enable precise, intricate designs on pottery and tiles, expanding artistic possibilities and improving production efficiency. The automotive industry also benefits from the use of printing screens and uses them for detailed surface treatments and painting processes. These cross-industry applications highlight the versatility of 3D printed printing screens, which offer cost-effective, customizable solutions for a wide range of production needs [8, 9].

The integration of 3D printing into industrial workflows is in line with global sustainability goals, particularly in terms of waste reduction and resource efficiency. The textile industry, considered one of the biggest polluters, is under increasing pressure to adopt environmentally friendly practices. 3D printing technologies support this change by enabling the reuse of materials, minimizing the amount of waste during the production process and facilitating the manufacture of high quality, recyclable products. Such practices contribute to the circular economy while maintaining the quality and functionality of manufactured products, highlighting the environmental benefits of additive manufacturing [6-11].

This study investigates the application of TPU polymer in the production of 3D printed printing screens for textile printing. It explores the material's unique properties, including its flexibility, adhesion and wear resistance, and examines its wider potential for cross-industry applications. Furthermore, the role of these printing screens in promoting sustainable manufacturing processes is evaluated in comparison to the classic preparation for screen-printing with photo emulsion. By combining cutting-edge materials with the precision of additive manufacturing, this research offers valuable insights into the intersection of technology, creativity and environmental protection.

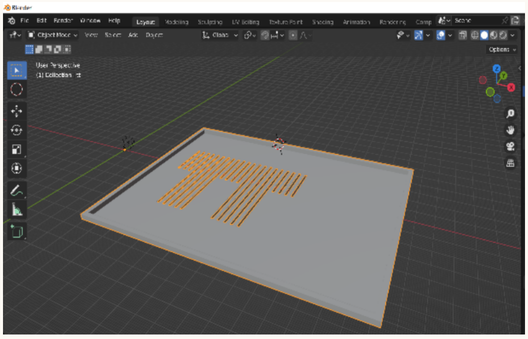
2. Experimental part

For the 3D modeling phase, computer-aided design (CAD) software, specifically Blender and Tinkercad, were utilized to develop the foundational structure of the research. Blender was chosen for its robust set of advanced modeling features, including precision sculpting, parametric adjustments, and high-fidelity rendering capabilities, which allowed for the creation of intricate and highly detailed designs (Figure 1 a, b). Tinkercad, with its user-friendly interface and ease of rapid prototyping, was used to iterate quickly on simpler components, ensuring an efficient design workflow that accommodated various levels of complexity (Figure 1 c).

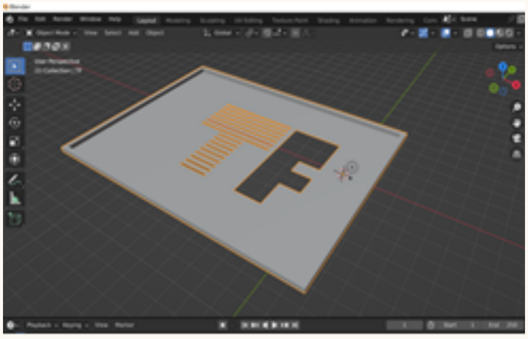
These tools complemented each other, enabling the seamless integration of artistic and functional elements into the final design. The 3D modelling process focused on achieving precise dimensions, structural integrity, and aesthetic appeal, ensuring the resulting model would meet the research technical and visual requirements.

Following the completion of the modeling stage, the finalized design was imported into Cura, a powerful slicing software. Cura was used to translate the 3D model into G-code, the language understood by 3D printers, optimizing the model for the specific printing parameters of the selected printer (Figure 1 d, e). This involved setting print resolution, layer height, infill density, support structures, and print speed to ensure optimal performance during the printing process. Cura's advanced features, such as previewing layer-by-layer slices and adjusting print settings for specific parts of the model, helped to minimize material waste and enhance print quality.

By leveraging the combined strengths of Blender, Tinkercad, and Cura, the modeling and preparation process was tailored to achieve a balance between precision, efficiency, and adaptability, setting a solid foundation for successful 3D printing.



a)



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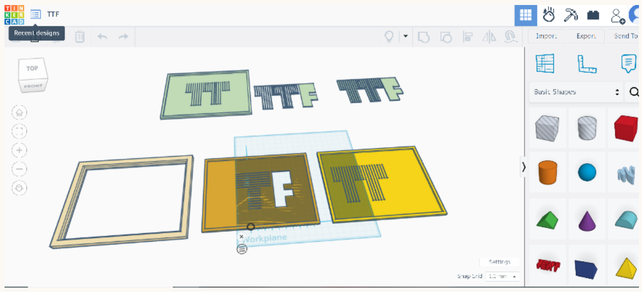

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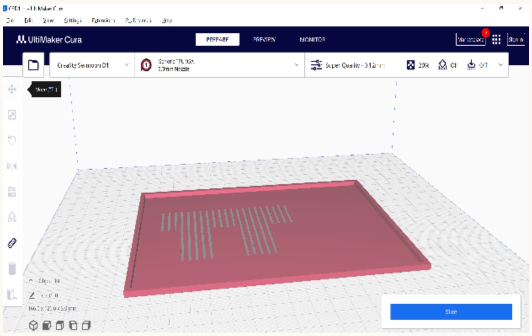

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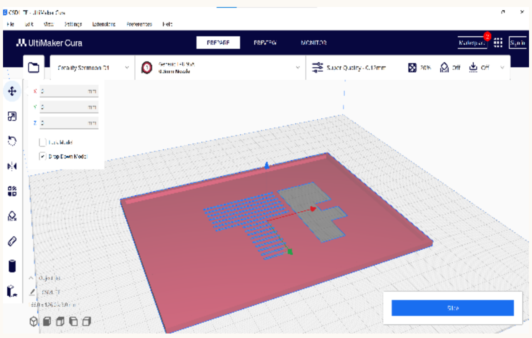

e)

Figure 1. 3D modeling using computer-aided design (CAD) software, a), b) Blender, c) Tinkercad and d), e) Cura software.

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2.1. Materials and methods

TPU the specified filament belongs to the group of elastic filaments for the FDM process. It belongs to the group of thermoplastic elastomers that are produced by stacking short- and long-chain diisocyanates to form blocks. By influencing the ratio and arrangement of these two groups, it is possible to obtain an extremely large number of variations of this polymer. Filament used in our research was TPU ERYONE (red) 1.75 mm. When printed in an FDM printer, the filament melts and takes on the predetermined shape according to the model, retaining all its elastic properties after cooling. It is extremely strong and abrasion-resistant and highly resistant to oils and greases. Printing with TPU requires careful preparation to achieve successful results. Preparation steps include choosing the right 3D printer, selecting appropriate settings and applying suitable techniques for handling TPU. Each of these factors plays a critical role in determining the final output quality when 3D printing with TPU.

The textile markers used with the textile printing screens provided vibrant, opaque and even coverage on the fabric. Different colours, including black, blue, green, purple, yellow and red, were applied to create layered designs (Figure 2 a.). The markers interacted effectively with the textile printing screens, creating detailed patterns with minimal bleeding. The result showed clear textures and grid-like patterns that highlighted the precision of the textile printing screens.

A unique addition to screen-printing was the use of a white, glow-in-the-dark Christmas spray (Figure 2 b.). When sprayed on, the spray created a festive, glowing effect that highlighted the design of the textile printing screens. The spray adhered well to the fabric and textile printing screens patterns, adding a layer of dimensionality and making the prints visually appealing in low light conditions. This innovative approach demonstrated the stencil's adaptability for creative applications beyond traditional textile markers.

a) b)

Figure 2. a) Textile markers (Ikea Loppstarr Textile Pens) b) Glow-in-the-Dark Spray (Volcke Aerosol Company nv, Belgium, Christmas snow).

In the fabrication phase, the Sermoon D1 3D printer was used to bring the digital designs to life (Figure 3). This printer was chosen for its reliable performance, high quality and versatile features that made it ideal for this research. The Sermoon D1 is a fully enclosed 3D printer that offers improved temperature stability during printing, which is particularly beneficial for materials that require constant thermal conditions. The enclosed design also contributes to improved safety and reduced noise, making it an efficient tool for precision work.

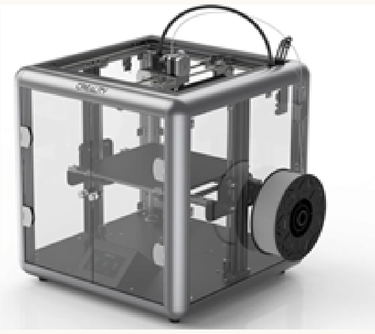

Figure 3. Sermoon D1 3D Printer.

Key features of the Sermoon D1 include:

- Large build volume: the printer offers a spacious build area of 280 x 260 x 310 mm, allowing the production of medium to large sized components or multiple smaller parts in a single pass.
- Dual Z-axis support: This feature ensures greater stability and accuracy during the printing process, minimizing deviations in the Z-axis and contributing to smoother layer transitions.
- Precision printing: With a high-resolution nozzle capable of producing layers as fine as 0.1 mm, the Sermoon D1 delivers detailed and highly accurate results, capturing the intricate details of CAD models.
- User-friendly interface: The printer is equipped with an intuitive touchscreen user interface that makes it easy to navigate and customize print settings as needed.
- Wide material compatibility: The printer supports a variety of filament types, including PLA, ABS, TPU and PETG, offering flexibility in material selection depending on the specific requirements of the research.

In this research, the Sermoon D1 played a crucial role in transforming the cut models from Cura into tangible prototypes. The printer was set up with optimized parameters (Table 1) including layer height, print speed and infill density, to ensure that the models met the desired mechanical and aesthetic standards. The closed build chamber was particularly beneficial for maintaining temperature consistency during extended print runs, ensuring strong layer adhesion and reducing the likelihood of warping.
To maximize efficiency, the research took advantage of the printer's large build volume by printing multiple components simultaneously whenever possible. This approach minimized downtime and increased productivity. In addition, the printer's high precision enabled the successful replication of complex geometries and fine details specified in the original designs, ensuring that the final products were exactly to the intended specifications. Overall, the Sermoon D1 proved to be an invaluable tool in the production process, providing the reliability and versatility required to achieve professional quality results.

Table 1. Printing parameters (standard and research).

Parameter	Standard TPU Parameters	Research Parameters
Material	TPU (Generic)	TPU ERYONE (red) 1.75 mm
Nozzle Type	Brass or Steel	Steel
Nozzle Diameter	0.4 mm	0.3 mm
Layer Height	0.1-0.3 mm	0.09 mm
Number of Bottom Layers	2-4	3
Infill Percentage	20-50 %	20 %
Printing Temperature	215-250 °C	228 °C
Bed Temperature	50-70 °C	60 °C
Bed Material	Glass or PEI	Glass
Printing Speed	30-60 mm/s	First Layer: 20 mm/s, Others: 50 mm/s
Retraction Distance	4-7 mm	6.5 mm
Retraction Speed	20-30 mm/s	25 mm/s
Cooling	Yes, 50-100 % fan	Yes, Fan 100 %
Support	Optional	No
Bed Adhesion	Skirt or Brim	3 Lines, 10 mm from the part

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3. Results and discussion

The 3D printed textile printing screens, made with a red TPU filament (Figure 4), have been successfully developed to produce sharp, clean shapes. The flexible and durable structure of the textile printing screen allowed for precise alignment during the screen printing process. The fine details were effectively translated into the design of the TTF (Faculty of Textile Technology) logo textile printing screens. Two different textile printing screens were made to utilize the shape and colours used in TTF logo (grey and red).

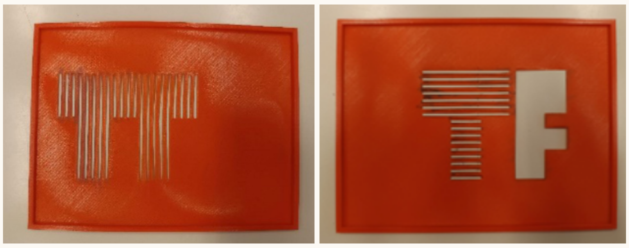
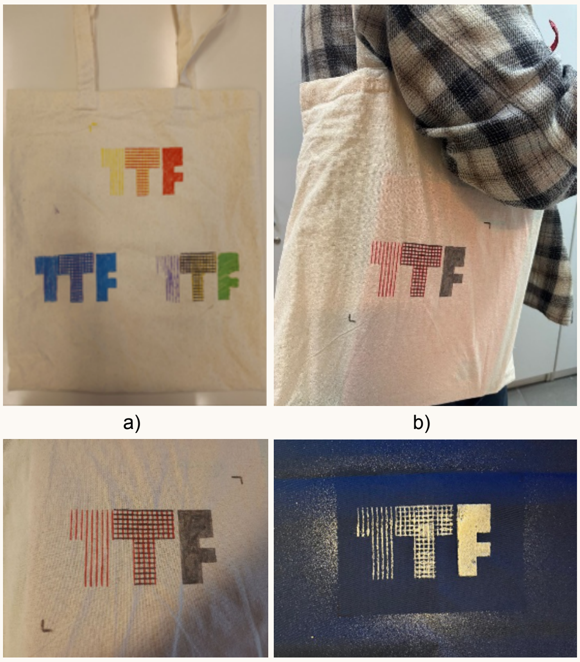


Figure 4. 3D printed textile printing screen.

The resulting printed designs displayed the following characteristics:

- Vivid colour patterns: the textile markers provided vibrant colours that highlighted the grid and line textures of the textile printing screens.
- Clear definition of the textile printing screens: The red 3D-printed textile printing screens enabled sharp and well-defined edges in the final prints.
- Glow-in-the-dark effect: The Christmas-themed spray gave the design a unique luminous quality, highlighting the design in low light and enhancing its decorative potential.
- Versatile applications: The textile printing screens were successfully used on a variety of materials and fabric backgrounds, proving their versatility for textile and creative print projects.
- Practical Observations:
  - Ease of use: the design of the textile printing screen facilitated effortless application and ensured precision with multiple uses.
  - Durability: The 3D printed material withstood repeated applications of markers and sprays without losing its structural integrity.
  - Creative versatility: The combination of different media (marker and glow-in-the-dark spray) demonstrated the potential of the textile printing screens for mixed media art and commercial designs.



a) b)

c) d)

Figure 5. Final screen-prints a) different colours b) bag on a model c) original TTF logo colours d) glow-in-the-dark Christmas spray.

The combination of 3D printing, textile markers and glow-in-the-dark spray delivered acceptable results, offering a blend of functional precision and creative flexibility. These results illustrate the success of integrating 3D printed tools with possible artistic and festive applications (Figure 5).

4. Conclusions

This research demonstrates the potential of integrating 3D printing technology with advanced materials such as thermoplastic polyurethane (TPU) for textile printing applications. The development of 3D printed textile printing screens emphasized the flexibility, durability and compatibility of the material with a variety of printing processes, including marker and spray printing. The TPU textile printing screens proved to be a cost-effective and sustainable alternative to conventional textile printing screens, offering high reusability and possible lower environmental impact. The trial results highlight the ability of the 3D printed textile printing screens to produce detailed and precise patterns, as demonstrated by the TTF logo made in form of two textile-printing screens, which are vibrant and well-defined designs. The successful application of these textile-printing screens on various fabrics and materials demonstrates their versatility and potential adaptability for both artistic and industrial purposes.

Furthermore, the application of 3D printing is in line with global sustainability goals as it reduces waste because of reusable/recyclable TPU polymer, promotes material efficiency and facilitates customization on demand. This study contributes to the growing field of sustainable textile manufacturing and highlights the transformative impact of combining additive manufacturing with cutting-edge materials. Future research could extend this work by exploring the use of different 3D printing materials and techniques to further improve performance and sustainability as well to research in environmental impact. In addition, exploring wider industrial applications could open up new opportunities for innovation in textile design and beyond. This study serves as a foundation for such advancements and underscores the importance of sustainable and versatile manufacturing solutions in today's textile industry.

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