EXPANDED SUMMARY

Additive manufacturing and the new approach to fashion: Innovation and Sustainability in the textile industry.

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Introduction

The fashion industry, shaped by a dynamic set of social and technological pressures, is one of the most economically relevant sectors globally, but it is also one of the most polluting (Lima; Dupont, 2018; Rocha, 2023). This paradox is mainly due to its traditional production model, characterized by high consumption of natural resources, intensive use of chemical processes, and the generation of substantial solid waste. The fast fashion phenomenon substantially exacerbates this problem by promoting an accelerated cycle of creation, production, and waste disposal, which fosters excessive consumption and results in severe environmental and social impacts (Hornburg et al., 2022).

However, a countercurrent is gaining strength: growing consumer awareness, amplified by the internet and social media, is driving movements to reduce environmental impact and promote ethical production. This new mindset drives the rise of slow fashion and conscious consumption, which prioritizes durability, artisanal production, and proper disposal, pressuring companies to align their practices with ethical and environmental values (Hornburg et al., 2022; Rocha, 2023).

In this context of transformation, Additive Manufacturing (AM), popularly known as 3D printing, emerges as a disruptive and promising technology. This article, therefore, aims to analyze the applications of additive manufacturing in textile and fashion production, highlighting its potential to revolutionize production processes, reduce environmental impacts, promote mass customization, and introduce new design and material paradigms, thus aligning with the demands for a more innovative and sustainable industry.

Methodology

This study is characterized as basic, descriptive, qualitative, and cross-sectional research. Its purpose is to generate new knowledge and broaden the understanding of the phenomenon of 3D printing in the textile and fashion sector, without the intention of seeking immediate practical applications (Bellé; Schenatto; Guadagnin, 2023).

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The methodological approach adopted was a bibliographic review, which began with the definition of a guiding research question: "How is the use of 3D printing characterized in the textile and fashion industry?". The literature mapping was conducted in three relevant scientific databases: Science Direct, Web of Science, and Periódicos CAPES. No specific time frame was established for the publications, aiming to cover the broadest possible scope of the topic's evolution.

The descriptors used were: "3D printing", "textile" and "fashion", which were transformed into the following search strings for the systematic query: (“3D printing” AND “textile industry”), (“impressão 3D” AND “indústria têxtil”), (“impressão 3D e moda”) and (“impressão 3D” e “moda”).

Articles in English and Portuguese were selected, resulting in a bibliographic corpus which served as the basis for the qualitative analysis of secondary data (Bellé; Schenatto; Guadagnin, 2023; Machado et al., 2023).

Results

The literature analysis showed that 3D printing represents a paradigm shift compared to traditional manufacturing methods, as it is an additive technique which builds products layer by layer from a digital model (Baek et al., 2022; Vanderploeg; Lee; Mamp, 2017). The process begins with virtual modeling in CAD (Computer-Aided Design) software, which is subsequently converted to the standard STL (STereoLithography) file format. This file is processed by "slicing" software, which converts it into two-dimensional layers and generates the machine code (G-code) to command the printer (Awad; Habash; Hansen, 2018).

Among the seven categories of AM processes, defined by the ABNT NBR ISO/ASTM 52900:2018 standard, Fused Deposition Modeling (FDM/FFF) stands out as the most versatile and widespread in the textile and fashion industry, especially due to its accessibility. Its applications are vast, such as Direct Printing on Textile Substrates, as it allows the deposition of molten polymers (like PLA) directly onto fabrics, creating multi-material systems. Adhesion is a critical factor, influenced by the fabric structure and printing parameters, with fabrics having lower thread density (e.g.,

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15 threads/cm) favoring polymer penetration and resulting in greater adhesive strength (Čuk et al., 2020).

Another approach is the development of textile structures and trims, as FDM can be used to manufacture flexible structures that mimic woven fabrics and knits, as well as trims like buttons and fasteners, demonstrating resistance in industrial laundry tests (Hornburg et al., 2022). Although the production of complete garments remains a challenge due to comfort and mobility issues, the technique is viable for creating seamless wearable components, bags, footwear, and accessories (Amador; Medeiros, 2023).

Additionally, FDM enables the integration of electronic components into flexible structures, boosting the development of smart clothing with embedded sensors (Chakraborty; Biswas, 2020). Other technologies are also relevant, such as Selective Laser Sintering (SLS), which uses a laser to fuse layers of powder (e.g., nylon), offering high freedom to create complex and customized shapes, and Stereolithography (SLA), known for its high precision (Xiao; Kan, 2022).

In the field of materials, advances are noticeable. Flexible materials, such as Thermoplastic Polyurethane (TPU) and Thermoplastic Elastomer (TPE), have overcome the initial rigidity of plastics, allowing the creation of more comfortable clothes with better draping (Amador; Medeiros, 2023). Simultaneously, sustainable materials are gaining ground, such as Polylactic Acid (PLA), a biodegradable biopolymer derived from renewable sources (corn, cassava), and bio-inks based on cellulose nanofibers, lignin, and polysaccharides (Borghei et al., 2024; Hernandez-Tenorio et al., 2025). The use of recycled materials, such as PET from bottles, is also made possible, contributing to a circular economy.

Emblematic cases illustrate the successful application of technology. Designer Iris Van Herpen is a pioneer in the use of 3D printing in haute couture, creating pieces of organic complexity impossible to achieve with traditional techniques. In contrast, designer Danií Peleg gained notoriety by creating an entirely 3D-printed dress for the opening ceremony of the Rio 2016 Paralympic Games. Nike, in collaboration with Cristiano Ronaldo, used the technology to produce customized

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cleats based on biomechanical data (Amador; Medeiros, 2023; Lima; Dupont, 2018; Rocha, 2018).

Despite the transformative potential, the literature points to persistent challenges: (i) Material limitations due to the difficulty in replicating essential properties of conventional textiles, such as breathability, softness, and durability to repeated washings; (ii) Costs and speed, as machinery costs and prolonged manufacturing time are still barriers to large-scale production; (iii) Intellectual property, since the ease of replicating digital files (CAD) intensifies the risks of piracy and copyright infringement; and (iv) Regulatory and privacy issues, as the integration of electronics in wearables raises concerns about the collection and protection of sensitive biometric data, requiring compliance with regulations for data protection.

Conclusions/Final Considerations

It has been concluded that additive manufacturing emerges as a profoundly transformative technology for the textile and fashion industries, offering innovative solutions that directly address the sector's urgent environmental, ethical, and production challenges. The study's goals were completely reached, demonstrating how 3D printing enables mass customization, drastic waste reduction, the creation of materials with advanced properties, and the redefinition of traditional design paradigms.

The potential of AM to consolidate a circular fashion model is undeniable. Projects exploring bio-inks, recycled materials, and decentralized business models (such as selling CAD files) point to a more sustainable and democratized future. However, the full realization of this potential is conditional on overcoming the identified technical, economic, and regulatory challenges. To this end, continuous investment in Research and Development (R&D) is imperative, focusing on creating new materials that combine flexibility, comfort, and durability; optimizing printing processes for gains in speed and efficiency; and developing technological solutions, such as the use of blockchain, for the protection of intellectual property. Finally, it has been stressed that the synergy from multidisciplinary collaboration between designers, engineers,

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material scientists, IT specialists, and fashion professionals is the fundamental catalyst to drive innovation and materialize, ethically and responsibly, the new approach that additive manufacturing proposes for the fashion universe[1].

[1] Grammar correction by: Aline Silva Dias, Master's student in Social Change and Political Participation – EACH-USP, Translator, CELTA / Cambridge Certified English Teacher. Email: alinedias.efl@gmail.com
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