REDUCING TEXTILE WASTE THROUGH DIGITAL TECHNOLOGIES: CASE STUDY OF CLO 3D AND AUDACES IN FASHION DESIGN

Professional paper
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ABSTRACT: *The work deals with the problem of excessive generation of textile waste in the fashion industry, with a special focus on the stages of design and production of clothing. Modern methods and digital technologies that enable waste minimization are analyzed, including zero-waste design, 3D simulations, digital prototyping and artificial intelligence. Special attention is paid to CLO 3D and Audaces software solutions, which enable more precise tailoring, optimization of material consumption and more efficient production of clothing. The implementation of these technologies contributes to sustainability, reducing the negative impact on the environment and moving towards a circular model of the fashion industry.*

Keywords: *textile waste, digital fashion, zero-waste design, CAD systems, sustainable production.*

SMANJENJE TEKSTILNOG OTPADA UZ POMOĆ DIGITALNIH TEHNOLOGIJA: STUDIJA SLUČAJA CLO 3D AND AUDACES SOFTVER

APSTRAKT: *Ovaj rad se bavi problemom prekomernog nastanka tekstilnog otpada u modnoj industriji, sa posebnim fokusom na faze dizajna i proizvodnje odeće. Analiziraju se savremene metode i digitalne tehnologije koje omogućavaju minimizaciju otpada, uključujući zero-waste dizajn, 3D simulacije, digitalno prototipiranje i veštačku inteligenciju. Posebna pažnja posvećena je softverskim rešenjima CLO 3D i Audaces, koja omogućavaju preciznije krojenje, optimizaciju potrošnje materijala i efikasniju proizvodnju. Implementacija ovih tehnologija doprinosi održivosti, smanjenju negativnog uticaja na životnu sredinu i prelasku ka cirkularnom modelu modne industrije.*

Ključne reči: *tekstilni otpad, digitalna moda, zero-waste dizajn, CAD sistemi, CLO 3D, održiva proizvodnja*

1. INTRODUCTION

The fashion industry is one of the most dynamic, but also the most environmentally problematic sectors of the modern economy. Fast fashion has led to a drastic increase in the production and consumption of clothing, resulting in huge amounts of textile waste. Currently, more than half of discarded clothing ends up in landfills or incinerators, while less than 1% of textile materials are recycled back into new clothing. This trend indicates an urgent need to change production and consumption models in the fashion industry to reduce the negative impact on the environment [1,2].
Waste prevention through clothing design is a key approach to reducing the negative impact, where modern digital tools such as 3D modeling, virtual prototyping and artificial intelligence play a significant role. These technologies enable more precise design, optimization of production and tailoring of clothing, thereby reducing the amount of textile waste [1,2].

2. METHODS FOR REDUCING WASTE IN THE GARMENT DESIGN PHASE

Waste in the fashion industry can be classified into several categories:

- **Garment design waste** - waste generated during designing, tailoring and production, including fabric scraps and incorrect patterns.
- **Production waste** – production waste and defective items created during mass production.
- **Post-consumer waste -** clothing that is discarded after use, including unsold stock [3].

The traditional garment design and manufacturing process tolerates two types of material loss:

- ***material losses of subjective reasons*** - caused by the flexibile structure of textile materials and the use of imperfect methods of creating markers, laying and cutting parts of clothing items.
- ***material losses of objective reasons*** - they arise due to complicated and fixed shapes of components, the need for the same and precise coordination of patterns on ready garments, specific properties of textile materials (different properties in the direction of warp and weft, edges, patterns, pile of materials, etc.) [4].

In order to reduce the loss of material due to the inefficient shapes of garment components, the fashion industry should focus on making styles with simplified forms but attractive designs using different colors, prints and surface decorations. Textile materials have to become a "precious resource" again, not only because of their increasing prices, but also because of the serious environmental problems caused by textile waste.
Reducing waste in the fashion industry is becoming a key aspect of sustainable production. Already at the stage of clothing design, by applying various techniques and technologies, it is possible to minimize waste and improve the efficiency of the production process. The methods used to reduce waste are [5]:

2.1. Optimization of material laying and cutting process

CAD (Computer-Aided Design) systems allow designers to plan precisely the arrangement of cut components on the fabric and with it to reduce unnecessary material waste. This process is known as "nesting", where the computer analyzes the optimal distribution of components on the fabric, taking into account its characteristics and specifics.

The use of automatic nesting reduces human error and allows for greater precision, resulting in less waste.

2.2. Zero-waste design

This method involves designing clothing in a way that completely eliminates waste, by cutting all parts of the garments from one piece of fabric, with no scraps. Zero-waste designers often use mathematical algorithms and creative techniques to connect all the cut parts and combine them into a single structure that leaves no waste. This approach is especially effective for creating simple, minimalist pieces like dresses, skirts, and shirts.

2.3. The use of recycled and ecological materials

Recycled materials, such as recycled plastic (PET) fabrics, old clothes or even agricultural waste can be used in the design phase. This reduces the need for new resources, thereby reducing the amount of waste in the production process.

Designers can use sustainable materials such as organic cotton, bamboo, or recycled synthetic fabrics that are more environmentally friendly and often easier to recycle.

2.4. Modular and transformable design

Modularni dizajn podrazumeva kreiranje odeće koja se može prilagoditi i transformisati na različite načine, čime se smanjuje potreba za novim proizvodima i višestrukim kupovinama. Na primer, jakna koja može postati prsluk, ili haljina koja se može pretvoriti u suknju.Multifunkcionalni komadi omogućavaju da jedan proizvod ima više namena, čime se smanjuje broj odeće koja se mora proizvoditi i kupovati, a time i količina otpada.

Modular design means creating clothes that can be adapted and transformed in different ways, thus reducing the need for new products and multiple purchases. For example, a jacket that can become a vest, or a dress that can be turned into a skirt. Transformable garments allow one product to have more than one purpose, thus reducing amounts of clothing that must be produced and purchased.

2.5. Upcycling and use of left over materials

Upcycling je proces u kojem se stari komadi odeće ili tkanine pretvaraju u nove, vrednije proizvode. Dizajneri mogu koristiti ostatke tkanina iz prethodnih kolekcija ili odbačene komade i preoblikovati ih u nove komade odeće, čime se smanjuje potreba za novim sirovinama.Ovaj pristup ne samo da smanjuje otpad, već i omogućava kreativan rad i jedinstvene proizvode.

Upcycling is the process of turning old pieces of clothing or fabric into new, more valuable products. Designers can use leftover fabrics from previous collections or discarded pieces

and transform them into new clothing, thus reducing the need for new raw materials. This approach not only reduces waste, but also enables creative work and unique products.

2.6. Using 3D simulations and digital prototyping

3D simulacije i digitalni prototipi omogućavaju dizajnerima da testiraju kako će proizvod izgledati na telu pre nego što započne fizička proizvodnja. To znači da se smanjuje potreba za fizičkim uzorcima i testiranjima, čime se štedi materijal.
Virtuelno isprobavanje uz pomoć specijalizovanih softvera omogućava da se dizajnira odeća sa potpunom preciznošću bez potrebe za višestrukim stvaranjem prototipova, čime se smanjuje količina otpada.
3D simulations and creation of digital prototypes allow designers to test how a ready garments will look on the body before physical production begins. This means that the need for physical samples and testing is reduced, saving material.
Virtual fitting with the help of specialized software makes it possible to design clothes with complete precision without the need for multiple prototypes, thus reducing the amount of waste.

2.7. Data-driven demand forecasting

Analyzing data on consumer habits, trends and preferences can help designers more accurately predict which clothes will be in demand, thereby reducing surplus production.
By introducing machine learning algorithms, it is possible to predict exactly how many pieces of certain styles should be produced, which allows greater precision in production planning.

3. OVERVIEW OF DIGITAL TECHNOLOGIES FOR CLOTHING DESIGNING AND PRODUCTION

The development of digital technologies has transformed the clothing design process, enabling designers and the industry to reduce waste, optimize material consumption and speed up the production cycle. Digitization in the fashion industry includes a wide range of tools, from computer-aided design (CAD) to artificial intelligence (AI) and virtual prototyping [6].

4. CASE STUDY: CLO 3D I AUDACES

4.1. CLO 3D

The CLO 3D program was developed by a team of experts at the Korean company "CLO Virtual Fashion Inc." and was presented for the first time in 2009. It was created in response to the need for a more efficient and precise way of designing clothes. It enables the simulation of garments in a virtual space before the production is started. Over the years, CLO 3D has experienced dynamic development, with frequent upgrades bringing new advanced cut and fabric simulation tools, improved user interface, and better integration with other software solutions [7].

One of the reasons for the popularity and application of this computer program is its effort to maximize the use of material (cut optimization), which directly contributes to the preservation of the environment through the reduction of textile waste (inter-cut loss), which is extremely important for the textile industry [7].
CLO 3D enables the creation of digital clothing prototypes that can be viewed from all angles, i.e. in a 3D virtual space, while simulating the fabric's behavior in real conditions [7].
Key functions of the CLO 3D program are:

- Simulation of a specific design and its adaptation as needed (see Fig.1),
- A significant reduction of the time required for product development,
- Accurate simulation of different fabrics, taking into account texture, weight and stretch,
- 3D visualization of clothing for improved product presentation,
- Creating personalized avatars and testing clothes on different body types [7].

4.1.1. *Advantages of CLO 3D program*

- Reduction of production costs – saves time and resources.
- Faster decision-making – enables quick changes and design reviews.
- More accurate fabric simulation – reduces the risk of errors in the later stages of production.
- Reduction of textile waste - reduction of the number of physical prototypes.
- Better fit and sizing – ability to test different fits on avatars.



Figure 1: Creation of 3D virtual style by CLO 3D[7]

4.1.2. *Disadvantages of CLO 3D program*

- Without clearly defined guidelines, simulation results can vary even when using the same basic data (avatars, cut parts, materials).
- Although developing simulation guidelines is time-consuming, it is critical to achieving reliable and consistent results.

- Also, guidelines should be regularly updated due to frequent upgrades of 3D simulation systems, which develop new functions and tools[7].

4.1.3. CLO 3D *Software's contribution to sustainability*

Računarska izrada prototipova modela i simulacija odeće pre početka proizvodnje izuzetno su važni za smanjenje tekstilnog otpada i održivu proizvodnju. Ovo važi kako za klasične metode konstruisanja odeće, tako i za zero-waste pristup [7].
Na slici 3. prikazana je pored smanjenja otpada, 3D simulacija koja omogućava preciznije prilagođavanje modela različitim tipovima tela, čime se poboljšava pristajanje i estetski kvalitet odevnog predmeta.
Computer-aided prototyping of models and simulation of garments before production is started are extremely important to reducing textile waste and support sustainable production. This is important for both to classical methods of constructing clothes and to the zero-waste approach [7].
Figure 2 shows how in addition to waste reduction, a 3D simulation that enables more precise adaptation of the style to different body types, thereby improving the fit and aesthetic quality of the garment.

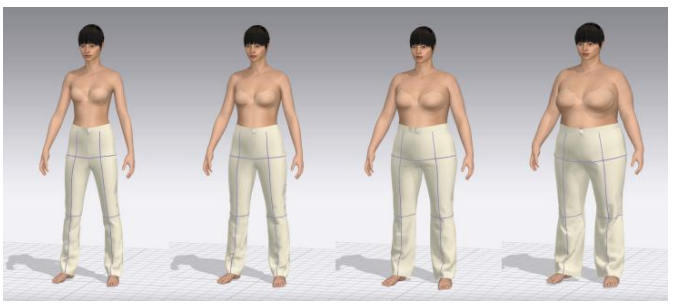


Figure 2: Adaptation of the style to different body types [7]

Limitations in fitting or lack of aesthetic criteria in the initial design idea can be corrected in pre -production phase, thus ensuring better acceptance of the product by consumers.

4.2. Audaces

Audaces is an integrated software system developed for the digital construction, modeling and optimization of clothing production. This software enables faster and more precise designing of patterns, automatic gradation of patterns and optimization of material consumption. Audaces can be used at small design studios and also at large capacity production sites. It enables cost reduction, increased efficiency and more sustainable production.
Audaces is particularly popular in the industrial manufacturing of clothing, as it combines 2D and 3D tools that help optimize the entire process, from designing to tailoring and manufacturing of the final products [8].

4.2.1 ***Main chracteristics and modules of Audaces Softwere***

Audaces offers several software modules, which together enable a complete digital clothing design process, (see Fig.3) [8].

4.2.2. ***Audaces 360 - Integrated ecosystem for digital design:***

- A complete solution for all phases of product development,
- Digital model archive for faster search and collection management,
- Connectivity with CAD and 3D tools for better design optimization [8].



Figure 3 : Audaces Softwere

4.2.3. ***Audaces Idea - Software for Fashion Design and Technical Sketching:***

- Enables the creation of technical drawings and fashion illustrations,
- Generates automatic size tables and technical specifications,
- Connects to tailoring systems for easier data transfer [8].

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5.2.6. ***Audaces Pattern - Digital Construction of Patterns (CAD Software)***

- Digital construction of cuts with precise lines and shapes,

- Automatic gradation to create multiple sizes from one basic model,
- The possibility of optimizing cutting parts in order to reduce material waste [8].

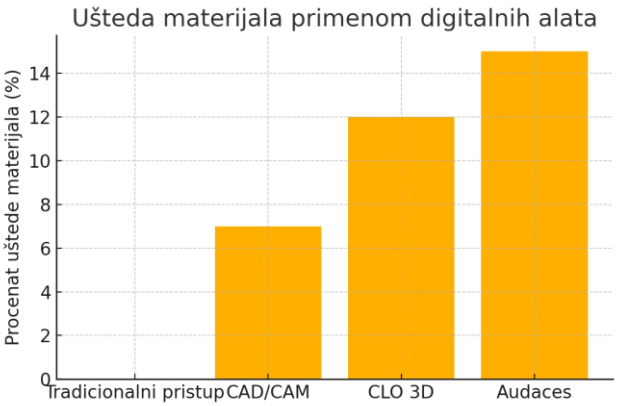


Figure 4: Material savings using CLO 3 and Audaces Softwere

5. CONCLUSION

The analysis of CLO 3D and Audaces software solutions clearly shows how modern digital technologies significantly contribute to the improvement of the process of designing and manufacturing clothes. CLO 3D stands out as a powerful tool for 3D garment simulation, enabling realistic rendering of models, adapting to different body types and significantly reducing the need for physical prototypes. This software not only speeds up the design process, but directly contributes to sustainability through cut optimization and reduction of textile waste.

On the other hand, Audaces represents a comprehensive system that integrates all stages of the development of a clothing product - from the idea and sketch, through the construction of patterns, to the optimization of manufacturing. Its modular structure ensures its flexible use depending on the user's needs, while the connection of 2D and 3D functionality ensure greater precision, efficiency and resource savings.

What both systems have in common is the contribution to the digitalization of the fashion industry and the transition to sustainable practices. The use of CLO 3D and Audaces software not only reduces production costs and time, but also increases the quality of final products, enabling better adaptation to the market and end users. Their integration into fashion and textile processes represents a key step towards the modernization of the industry and a more responsible approach to clothing production.

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