

Design, research and development of a collection of women's high-heeled shoes using polylactide 3D printing – Part 1: Exploration of design principles

Dizajn, istraživanje i razvoj kolekcije ženskih cipela visokih potpetica primjenom 3D ispisa od polilaktida – 1. dio: Istraživanje dizajnerskih principa

Scientific Paper / Znanstveni rad

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Abstract

The footwear industry is constantly evolving, with sustainability and the integration of digital technologies among the most important trends. Additive manufacturing, popularly known as 3D printing, is an advanced technology that is significantly changing the design and manufacturing process of footwear. The paper shows the development of the author's avant-garde women's shoe collection using 3D printed high heels made of polylactide (PLA) in a fused deposition modeling (FDM) process on a desktop 3D printer. In this first part of the work, the design of the author's women's shoe collection is presented. The collection brings technology and man into synergy through the stylization of human organs on the model of a woman's shoe. The experimental part shows the first part of the development of the prototype of women's shoes using digital tools, from concept design, conceptual solutions, elaboration of selected conceptual solutions for realization through color, selection of materials, to project drawings.

Keywords: fused deposition modeling; 3D printing; shoes design; concept design; project drawing

Sažetak

Industrija obuće kontinuirano se razvija, a održivost i integracija digitalnih tehnologija nameću se kao ključni trendovi. Aditivna proizvodnja, popularno zvana 3D printanje, prednjači kao napredna tehnologija koja donosi značajne promjene u procesima dizajna i izrade obuće. Rad prikazuje razvoj autorske kolekcije avangardnih ženskih cipela primjenom 3D ispisa visokih potpetica od polilaktida (PLA) postupkom taložnog očvršćivanja (engl. Fused Deposition Modeling – FDM) na stolnom 3D pisaču. U ovom, prvom djelu rada, prikazano je dizajnersko osmišljavanje autorske kolekcije ženskih cipela visokih potpetica. Kolekcija postavlja tehnologiju i čovjeka u sinergiju kroz stilizaciju ljudskih organa na modelu ženske salonke cipele. Eksperimentalni dio prikazuje prvi dio razvoja prototipa ženskih cipela primjenom digitalnih alata, od koncept dizajna, idejnih rješenja, razrade odabranih idejnih rješenja za realizaciju po boji, odabira materijala, do projektnih crteža.

Ključne riječi: taložno očvršćivanje; 3D ispis; dizajn obuće; koncept dizajn; projektni crtež

1. Introduction

Sustainability and the integration of digital technologies are key trends in the footwear industry, with additive manufacturing (AM) emerging as an advanced technology that is significantly changing the process of footwear development and production. The ever-growing number of footwear models on the market, offered in different styles, types and trends, requires innovative and fast solutions, and it is additive manufacturing that makes it possible to meet these demands. One of the advantages of additive manufacturing is the production of products in a short time directly from a computer model (e.g. Computer Aided Design - CAD) on the device, without the need for additional tools. There are different types of additive manufacturing, but all are based on creating a shape by depositing material layer by layer, which enables the production of complex geometric shapes [1, 2]. Additive processes in footwear production enable the quick and easy production of prototypes and small batches of products, including personalized models. This technology significantly reduces the time and cost of

developing new models, which is particularly important in today's dynamic footwear market that requires fast and innovative solutions. Unlike traditional processes, which often require the production of expensive and time-consuming prototypes, 3D printing allows designers to quickly test creative ideas and/or design solutions [3]. In addition to speed, additive processes offer greater design flexibility and enable the production of complex geometric shapes that are difficult or impossible to realize with conventional processes. This is particularly evident in the production of heels, where 3D printing opens up new possibilities for creative design and personalization. Planning the application of 3D printing in the realization of the prototype of a shoe salon allows the author to realize an artistic vision in the realization of a prototype with unconventional and complex shapes, which would be extremely difficult to achieve with traditional methods.

Design is the conception and creation of new products, which can be ideas, interactions, information, objects, writings, books, posters, products, places, signs, systems, services, furniture, websites and much more. Designers imagine and explore something, use their skills

and abilities in collaboration with others, want to develop ideas and change what already exists. Design is present in all industries, including shoe production. Shoe designers are responsible for the look, style, colors and patterns that end up as a finished product on shoe store shelves. However, the design process itself requires a balance between creative and artistic inspiration and attention to the comfort of the shoes, the effectiveness of the materials selected, the construction and technological capabilities of the shoe production and more [4]. The designer is just one in a team of experts responsible for the process of designing and manufacturing footwear, especially when it comes to designing a specific product according to the requirements of a customer, a company or a project. The process of shoe design begins with an inspiration and an idea, the research of the chosen stimulus or idea and the collection of data. After analyzing and synthesizing the collected data, the design process begins with creating sketches, experimenting with shapes, materials, textures and colors related to the actual idea for the desired product [4,5].

Today's designers face many challenges, but also opportunities. The development of digital technologies enables the use of advanced visualization and modelling tools that open up new possibilities and speed up the design and development process. The entire process of designing the Garbody 4.0 collection, from concept design to the creation of conceptual solutions, the development of models by color to project drawings of selected models for the creation of prototypes, was carried out using digital tools in the vector graphics program Inkscape.

2. Experimental part

The experimental part of the work presents the development stages of the author's mini-collection of avant-garde women's shoes using digital tools and technologies, focusing on the research approach in the design process. The process of designing a collection of women's shoes is described and visually documented, from the conceptual design, the development of conceptual solutions, the selection of materials by color and properties for the production of shoe uppers and heels, to project drawings with technical instructions for production.

2.1. Design of a women's shoe collection "Garbody - 4.0" - Concept design

The experimental part of the thesis presents the development phases of the author's mini-collection of avant-garde women's shoes using digital tools and technologies, focusing on the research approach in the design process.

The process of designing a collection of women's shoes is described and visually documented, from the conceptual design, the development of conceptual solutions, the selection of materials by color and properties for the production of shoe uppers and heels, to project drawings with technical instructions for production. The first phase of collection development is the collection of ideas in the form of a design concept, which shows the designer's thoughts on inspiration and the concept and vision of the future product. The name of the women's shoe collection "Garbody - 4.0" was created according to the author's approach to the theme of the collection by combining the words garbage and body. The term Garbody reflects the relationship of modern man to himself, nature and everything that surrounds him. The addition of "4.0" refers to the fourth industrial revolution, but has a different symbolism here: it refers to the need for a spiritual revolution, particularly in connection with the growth of individual and social awareness and the search for new values that meet the challenges of today. The design concept of the "Garbody 4.0" collection (Figure 1a) is inspired by the human organs, whose structure symbolizes the complexity and harmony of the body. The choice of the pump and the high heel as the dominant model in the designed collection of women's shoes reinforces this contrast, as the simple lines and elegance of the classic pump provide an ideal setting to emphasize the rich complexity of the human organism.

The works inspired by the idea described were created using the computer vector program Inkscape. Digital skills in using computer

programs to create graphics or drawings are essential for modern designers. They allow for shorter creation time, easy and quick corrections and brilliant visual presentations.

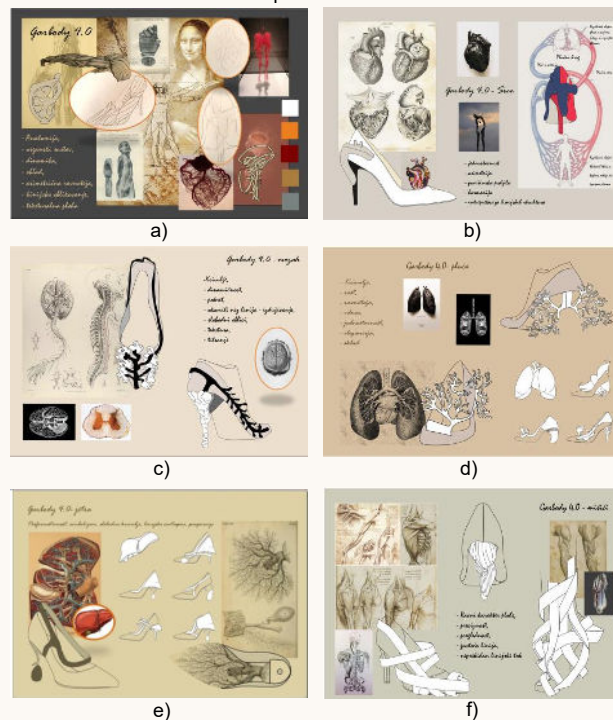


Figure 1. Concept design of the women's shoe collection "Garbody 4.0": a) core, b) heart, c) brain, d) lungs, e) liver and f) muscles

Individual concepts inspired by individual human organs were also designed: Heart, Brain, Lungs, Liver and Muscles (Figure 1b-f), which also include drawings by Leonardo da Vinci as inspiration, exhibited in the 2013 exhibition "Leonardo da Vinci: The Mechanics of Man at the Queen's Gallery" in Edinburgh.

2.2. Creation of concept designs for women's shoes

After visualizing the conceptual design, the collected information is brought together and the conceptual design for women's pumps is created, focusing on several main guidelines aimed at conveying the idea, refining the composition and creating balance. In this development phase, the design of the future product is finalized. During the creation of the conceptual designs, designers often research current fashion trends to check the originality of the conceptual designs. Figure 2 shows concept designs inspired by the concept designs "Garbody 4.0 - Heart" and "Garbody 4.0 - Brain".

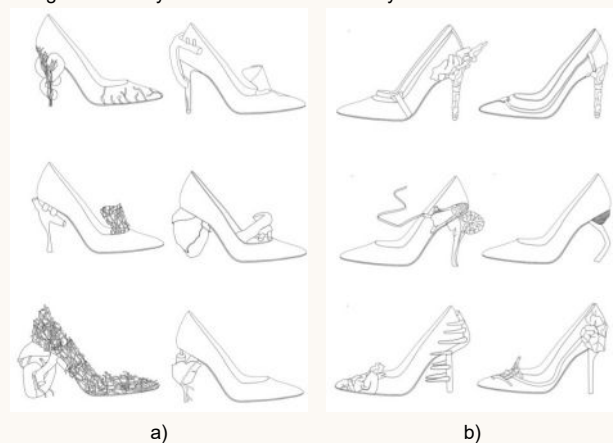


Figure 2. Conceptual solutions for lounge shoes for women, inspired by the concept design: a) "Garbody 4.0 - Heart" and b) "Garbody 4.0 - Brain"

Two conceptual solutions were selected that met the aesthetic, technical and anatomical requirements for the creation of the prototype, and the development of a colour model was started in order to obtain as clear an idea as possible of the appearance of the final product (Figure 3).



Figure 3. Development of selected conceptual solutions by color: a) "Garbody 4.0 - Heart" and b) "Garbody 4.0 - Brain"

2.3. Materials for the realization of prototypes of women's shoe

In addition to the esthetic factor, the choice of material is decisive for the quality, comfort and appearance of the shoe and is therefore one of the most important processes in the design and development of the future product. The process begins with the selection of available colors of PLA polymers used for the production of high heels in the 3D printing process on a desktop 3D printer. There is a wide range of PLA polymers on the market in different colors and with different effects, but the most favorable polymers are the primary and secondary colors and the achromatic polymers. According to the conceptual solutions developed, light red, dark red with glitter effect and orange PLA polymers were selected (Figure 4a). Leather was chosen for the upper of the shoe as it is a traditional and still very popular material for shoes. The properties that make leather ideal for shoe manufacturing are durability, flexibility and breathability. Depending on the chosen colors of the PLA polymers, the most similar or most suitable leather samples were selected. Bovine leather, lacquer-tanned bovine leather and chrome-tanned bovine leather were selected, which produces the most supple and finest leather. Leather samples of different color, texture and type for both prototypes are shown in Figure 4b.

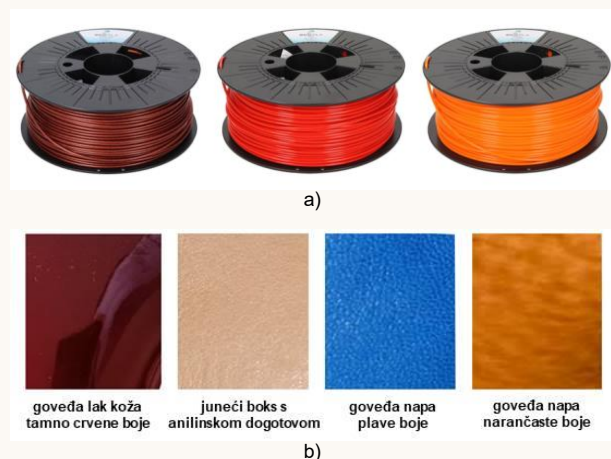


Figure 4. Samples of the materials used: a) PLA polymers in dark red color with glitter effect, red and orange for the heels and b) leather samples for the production of the upper of the shoe.

2.4. Development of conceptual solutions for the realization of the prototype

The chosen colors of the materials for the realization of the prototype also reflect the symbolism of the effect of the colors in connection with the inspiration and the conceptual design concept. In the "Garbody 4.0 - Heart" model, the red color of the outer part symbolizes the strength, dynamism and power of the human body, while the color of the skin, which soothes the composition, shows the earthy color, balance, connection with nature and with oneself. The combination of orange and its complementary blue in the "Garbody 4.0 - brain" model was chosen to evoke the complexity and energy of the brain, symbolizing joy, dynamism and energy, while the brown color balances the composition and adds an element of naturalness. The visualization of the selected conceptual solutions for the creation of a prototype of a platform shoe, in accordance with the selected materials, is visible in fashion drawings (Figure 5) showing the outsides and insides of women's shoes. Figure 5a shows platform shoes with a heel that stylizes the circulation of blood through the heart, while the upper part of the shoe, divided into two parts, symbolizes the right and left ventricles of the heart. The embossed heel of prototype number 2 (Figure 5b) represents the asymmetrical hemispheres of the brain, while the upper part symbolizes the spinal cord as the main communication pathway between the brain and the body. The fashion drawings represent a combination of artistic vision, knowledge of the technological and design requirements of shoe upper production and an understanding of the possibilities of 3D printing in the production of high-heeled shoes. They are also the starting point for the further process of model development and preparation for the realization of the prototype.



Figure 5. Fashion drawings: a) prototype 1 and b) prototype 2

The construction drawings are created on the basis of the conceptual solutions developed. A construction drawing is a precise drawing of a model in which all elements are defined: Shape, cutting lines, connection types, material (main, auxiliary) from at least three views [5]. Figures 6a and 6b show design drawings from four views with technical and technological instructions for production. Defined technological instructions are important for the modeling and construction process in order to know where to add the prescribed allowances for seams, where the seams for technological markings are located, the location of the material composition, the method of edge processing, marked decorative seams, etc.

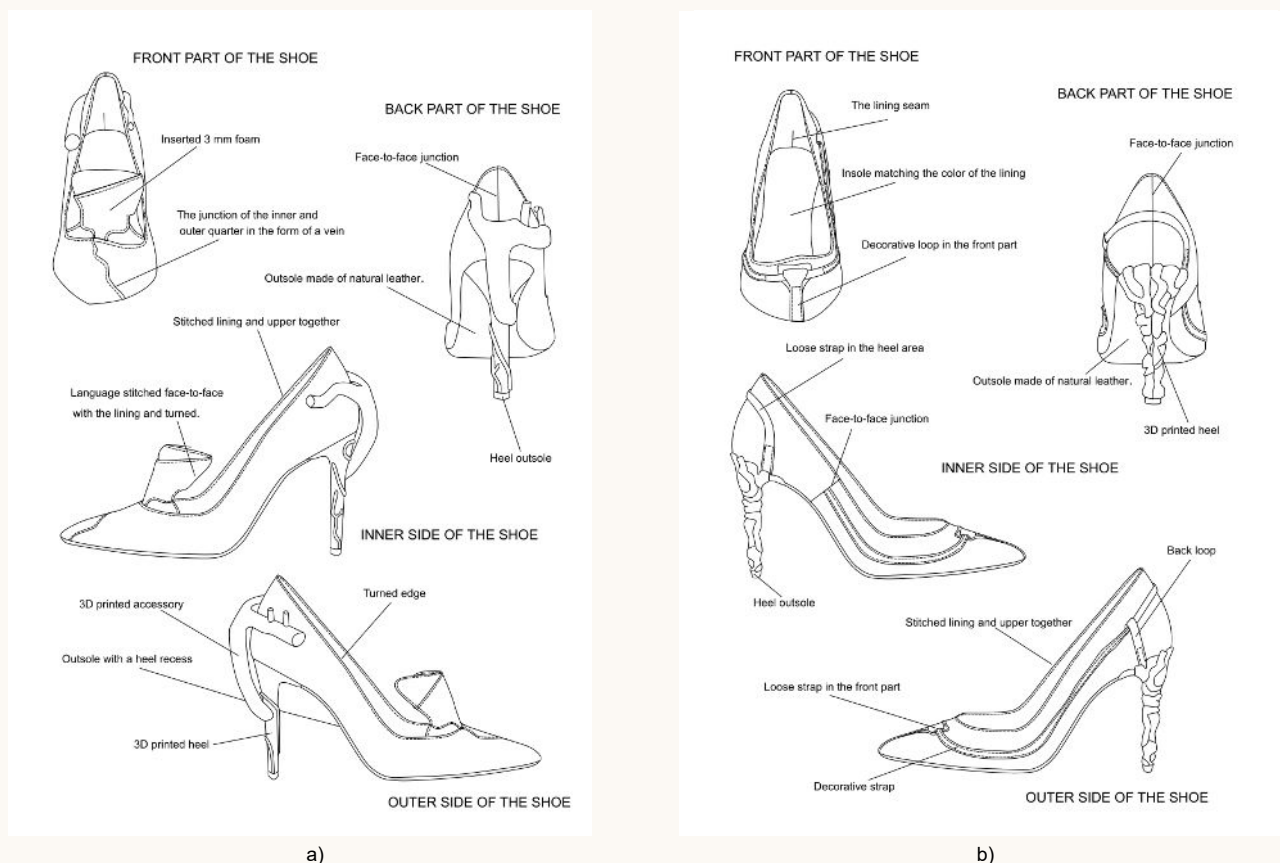


Figure 6. Design drawings of women's pumps: a) Prototype 1 "Garbody 4.0 - Heart" and b) Prototype 2 "Garbody 4.0 - Brain"

3. Conclusions

This article presents the results of an investigation into the possibilities of using digital tools in the process of designing and developing shoe prototypes. The collection of women's pumps is an expression of personal reflections on the relationship between man and himself and the natural world. At a time when the opinions of others are imposed by the media, the original way of thinking remains unused and is

increasingly suppressed. We lose touch with what really makes us happy while we accept what is imposed on us as desirable. The design solutions of the women's shoe collection are a symbol of a new beginning - a spark that promotes acceptance and understanding of one's own body. An important role is played by the use of modern technologies that enable precise and impressive visualization of the author's concept and design.

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