Industry 4.0 for fashion products – Case studies using 3D technology

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T Spahiu[1], A Manavis[2], Z Kazlacheva[3], H Almeida[4], P Kyratsis[2]

[1] Polytechnic University of Tirana, Faculty of Mechanical Engineering, Textile and Fashion Department, Albania
[2] University of Western Macedonia, Department of Product and Systems Design Engineering, Kila Kozani, GR50100, Greece
[3] Faculty of Technics and Technologies, Trakia University, Bulgaria
Graf Ignatiev 38, 8600 Yambol, Bulgaria
[4] School of Technology and Management, Polytechnic Institute of Leiria, Leiria, Portugal

e-mail: tspahiu@fim.edu.al

Abstract. The Fourth Industrial Revolution is based on digitalization where virtual and physical systems of manufacturing are linked and operate together. Fashion products are of a great interest not only as items used to cover and protect the body but even to express individuality, personality and attractiveness. Due to the high interest of consumers for fashion items or products, fashion industry is one of the most important industries globally due to its effect on economic growth. As a result, companies try to invest continually on new technologies by implementing them in various processes of production. The aim of this paper is to present here the implementation of advanced technologies for various fashion products as garments, jewelery and accessories. These products are modelled, evaluated and produced by using 3D modelling software, simulation and additive manufacturing as some of the pillars of Industry 4.0 will be presented. The reduced time, waste and advantages to create, visualize and evaluate products at early stages of product creation are some of the advantages of these technologies, part of Industry 4.0 in the fashion industry.

1. Introduction

Fashion products are used in everyday life and they cover a wide range of items or goods as clothing, footwear, jewellery, handbags, accessories, etc. These products are in continuous changes according to consumer demands and functionality, which change frequently. They are of a great interest not only as items used to cover and protect the body as clothing and footwear but even to express individuality, personality and attractiveness. Due to the high interest of consumers for fashion items or products, fashion industry is one of the most important industries globally with a huge effect in economic growth. As a result, companies try to invest continually on new technologies by implementing them in various process of production.

Due to technological advances the way of product development has undergone many changes. These changes are reflected in style, quality, personalization and even innovation. In its traditional way of product development there are different steps till the realization of the final product. But advanced technologies and their widespread use for product design, following by its assessment through simulation and equipment involved in manufacturing show their importance in various steps of product development, from conceptualization to the final product.

Technological trends identified to be primarily instrumental in shaping industrial production are Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, Internet of Things (IoT), Cyber-Security, The Cloud, Additive Manufacturing, and Augmented Reality [1]. According to a study conducted by da Silva et al., the results reveals several factors as technical, organizational, project based or external should be considered in the implementation of digital manufacturing in a company [2].

Impact of new technologies are evident with applications in every area of production by accelerating production time, reduction of material wastage and increasing the quality of products or systems through process shorting, automation simulation. Although these attempts are at a low rate, they show the raising awareness of companies and stakeholders to contribute to a sustainable fashion industry, where the role of designers to create sustainable fashion products is mostly related by choosing sustainable materials. As a result, researchers propose closer collaboration between academics, industrial practitioners, policymakers and consumers. This will result in fostering the rapid transformation of fashion industry [3].

Innovations in production are part of the Industry 4.0 and with the current state it requires the integration of 3D printing as part of Industry 4.0 into engineering teaching and fashion disciplines [4, 5]. The results are a student gradually trained and more conscious of the environment and economy [6]. So it is convenient that the supply-side actors of industry 4.0 continue to provide education and training, establishing users groups and networks can promote organizational learning for Industry 4.0 [7].Moreover younger generations are able to pay to sustainability and circular economy by causing fashion companies to redirect their strategic approach toward transforming social responsibility and sustainability into a competitive opportunity to benefit both the individual companies and the overall sector [8].

The rising demand for customized products and linked with the geometrical complexity are more valuable in digital manufacturing [9]. Combining mass production and custom made according to consumer preferences by 3D printing can contribute to sustainability [10]. The cases of 3D printing in fashion industry still remain scarce, due to the lack of material properties still far away from the ones used in traditional clothing manufacturing. But the promises are high for jewellery and shoe production, especially the sole due to similarities with materials used in the traditional manufacturing process. Moreover, 3D printing on textile is one of the most used where additional characteristics can be added to this multi-material system [11]. There are still concerns if it becomes available at the household level, related with the increase use by prosumers to experiment designs [12, 13]. The technological and digital transformation shows that the fashion industry will undergo profound changes as the case of smart clothes, where products should generate value by technical and digital characteristics and on the same time with a good design to establish a strong emotional relationship with consumers [14, 15].

2. Garment design and simulation

Garment design is a process to include all the design elements and to create a product visually attractive and offering comfort to the wearer. Fashion designers tries to express their art through garment flats and pattern makers tries to translate these designs by using anthropometric data according to sizing tables and bearing in mind the type of textile that is going to be used for production. In its traditional way of garment construction, it requires time, trials and errors that are part of this process leading to higher costs related to material waste and labour. But advancement of computer graphics has led to a more reliable process of virtual garment construction. These advancements try to simulate the whole process of garment from concept to production in a virtual environment. There is wide range of software used for garment design from open source to professional CAD which offers various tools to simplify the process of pattern development in fashion industry [16]. These tools have become more sophisticated, and engineers/researchers consider this challenge as an opportunity for more accurate design, manufacturing, and simulations [17].

Garment simulation is a process to create virtual replicas of models and access the garment fit before creating the physical sample. Accessing the garment drape and fit over 3D avatar or personalized body models are realized simultaneously on the 3D window. Simulation as one of the

pillars of Industry 4.0 is of a great interest for this industry and its integration is seen to have a pivotal role and even named as at the heart of Industry 4.0 [18]. Integration of ICT technologies in the process of garment design can have a huge impact in fashion industry and customers behaviours [19].

Trials and errors requiring times and costs now can be avoided by the implementation of these systems. Standard methods used for pattern making of various items are based on standard human body models. But due to the differences that exist between human bodies these are translated to a poor fit. As a result, companies try to use their own method to create various items according to their target group, by updating their sizing tables according to their measurements, including garment simulation.

3. Jewelery design based on nature

Jewelery products are items used since antiquity to decorate the body. They vary in shapes and materials used for manufacturing. Due to the advancements of technology, the method used for production has undergone different changes. Computer aided design offers powerful tools for the designing process of jewellery by reducing costs and optimizing the whole production efficiency [20], [21]. Among 3D modelling software developed specifically for jewelery design, there are cases of implemented 3D modelling software applications. The packages of CAD jewelery offer detailed tools for designing and photorealistic images. These are a key element used for marketing and product assessment by avoiding the physical model. Jewelery design is a process of expressing creativity, during which several designs with minor changes are created. Generative design systems for jewelery applications can support designers to generate designs [22] and how industrial designers can use the field of parametric and computational modelling to foster their creativity [23].

Recently, 3D printing also known as Additive manufacturing technology has been used to print objects from a digital template, using several materials, including metals, among hundred other materials, plastic, metal, nylon [24].

4. Materials and methods

This work deals with the use of advanced technologies for fashion products. The workflow proposed and followed in this work is presented in Figure 1.

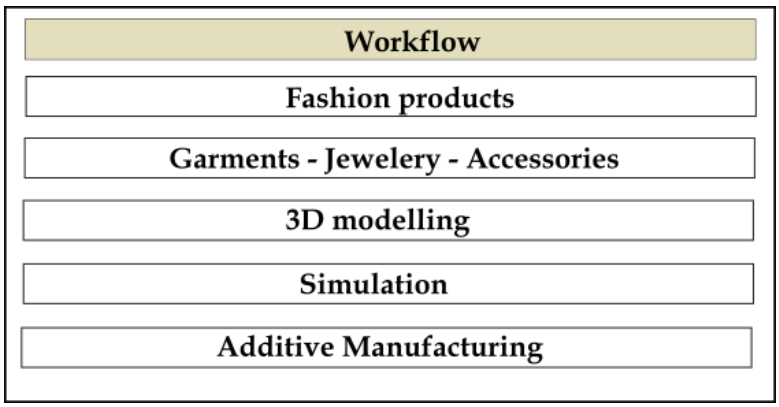

Figure 1. Workflow for garment production.

These case studies are garments, jewelery and accessories. Garment design and simulation are realized on 3D modelling software CLO 3D from CLO Virtual Fashion Inc.3D body models are personalized with anthropometric data according to the participants part of this study.

The other products realized in this work are jewellery and accessories. By using engineering and reverse engineering processes 3D models are created. In reverse engineering a real object is digitized using a 3D laser scanner system Konica Minolta Vivid 910 and by following various steps to conclude with precise 3D model. In the other process of engineering a product is created by modelling in CAD software. In this work a 3D modelling Tinkercad from Autodesk Inc is used for creating the products.

Final products are realized by using additive manufacturing technology. A 3D printer Geeetech A30 3D printer based on Fused Deposition Technology is used for 3D printing real objects. Preparing 3D models for 3D printing is done on CURA slicing software and exported as a G-code. In Figure 2, a view of 3D printer used is depicted.

Figure 2. Geeetech A30 3D printer.

5. Results and discussion

5.1. Virtual vs. Real garments

3D technology and computer graphics offer great tools in the whole process of garment production. In order to fulfil customer's requirements, 3D software give the possibility to simulate, evaluate and modify within the same environment, by shortening time and realizing a virtual presentation of garment prototypes. Starting from an idea to a virtual garment design, sewn, draped over 3D body model and evaluated in terms of fit can contribute even in sustainable fashion. This is evident by realizing adjustments, modifications, and reducing the number of prototypes evaluated as not attractive. As an example, to bring here the advantages of virtual prototyping, three different types of garments are depicted. The process starts with digital anthropometric data generated from 3D body scanning of the participants, which will then be used to personalise the 3D body models that exist in the software's library. The patterns of two dresses and one jumpsuit are modelled on garment pattern making software Lectra Modaris, exported and imported in CLO 3D. The real time interactivity by performing instantly changes as 2D pattern modifications, and other details related to colours or textile improves quality of garment design at early stages of the process of garment production. The generated pressure maps of each model confirm the garment fit over 3D body models personalized with anthropometric data. Interacting by pattern modification and evaluating models in early steps of production makes the whole process attractive for the user with a faster virtualization of modelled product and in the same time by serving as inspirations to create new designs. Moreover, the virtual process of garment production contributes to time and cost reduction by avoiding creation of physical garments and waste generated from it and in the same time contributing to sustainability.

At the end 2D patterns are exported, cut and used for the process of real garment production. Comparisons of real versus virtual garment samples are presented in Figure 3. As can be seen from the images the similarities between real and virtual garments are evident by confirming again the important role of virtual simulation for garment products.

Figure 3. From virtual model to real garment.

5.2. Jewelery and accessories

Inspirations taken from nature for various applications are evident in a wide number of applications. Known as Biomimicry or biomimetics is the practise to learn and imitate nature regarding forms, process and systems with the goal to solve human problems. Biomimicry is derived from the Greek word, where bios mean life and mimesis means imitation. Based on nature inspiration the case of flowers for jewellery design is not a new topic. But our focus is to present new technologies as 3D modelling and rapid prototyping as two pillars of Industry 4.0.

Earrings are accessories used by women's in everyday life. Their shapes, colours and materials vary. In this work, inspirations taken by flower models are presented. Based on the flower image, the 2D concept is realized, which is then modelled on a web-based 3D modelling software Tinkercad from Autodesk Inc. Exported 3D models are further imported on the slicing software Cura from Ultimaker produced through additive manufacturing based on FDM technology. The material Polylactic Acid) known as PLA, which is a vegetable based plastic material and known as one of the most environmentally friendly material. It is a fully biodegradable thermoplastic polymer, usually produced from corn and sugarcane. Figure 4 and Figure 5 present flowcharts followed to create earrings models. By taking inspirations from the real flower images, to 2D shapes and after 3D modelling of flower models. At the end the final products generated through the use of additive manufacturing technology.

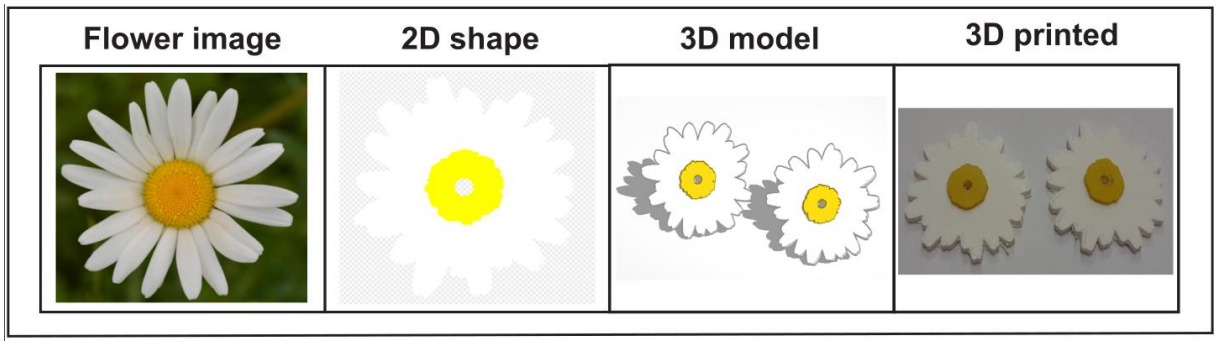

Figure 4. Flowchart from real flower to 2D shapes, the 3D model and real model taken by 3D printing.

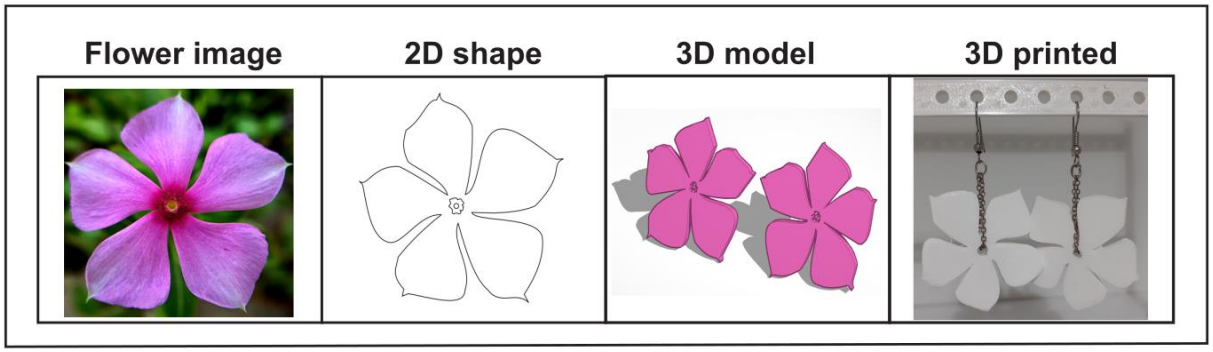

Figure 5. Flowchart from real flower to 2D shapes, the 3D model and real model taken by 3D printing.

Another case within creative design presented in this work is the walnut model. The ancient Greeks, about 2800 years ago found that walnuts are very similar to brain shape in a small size as they have folds and divided halves with distinct left and right hemispheres. Moreover, they are covered by a hard shell like our skull. Taking into account their shape, a walnut fruit is taken to create various products from it. By using advanced technologies as 3D scanning allows us to capture the 3D shape of a model and create virtual replicas of it, which can be further elaborated, modified and used to create various products. The scanning system used in this work is a laser scanning system Konica Minolta

VIVID 910. Following with data elaboration and merging the single scans, to create the digital copy of the walnut model. This digital model is further taken as a base for the other products.

The first case is the one of the earrings model taken from dividing the walnut model in halves. In the other case the shape of the walnut inside is included by resulting in another variant of earring model. The other products created inspired by walnut model are the ring models. In the first model of the ring, a hollow with the ring size is created. In the second and third cases, half of the walnut is used as the upper part of the ring model. Two other products are button and medallion. Again, here using as a base the 3D walnut model the resulting models are presented. Each one the models can now by manufactured by additive manufacturing technologies as FDM, a non-expensive technology compared to the other types of technologies.

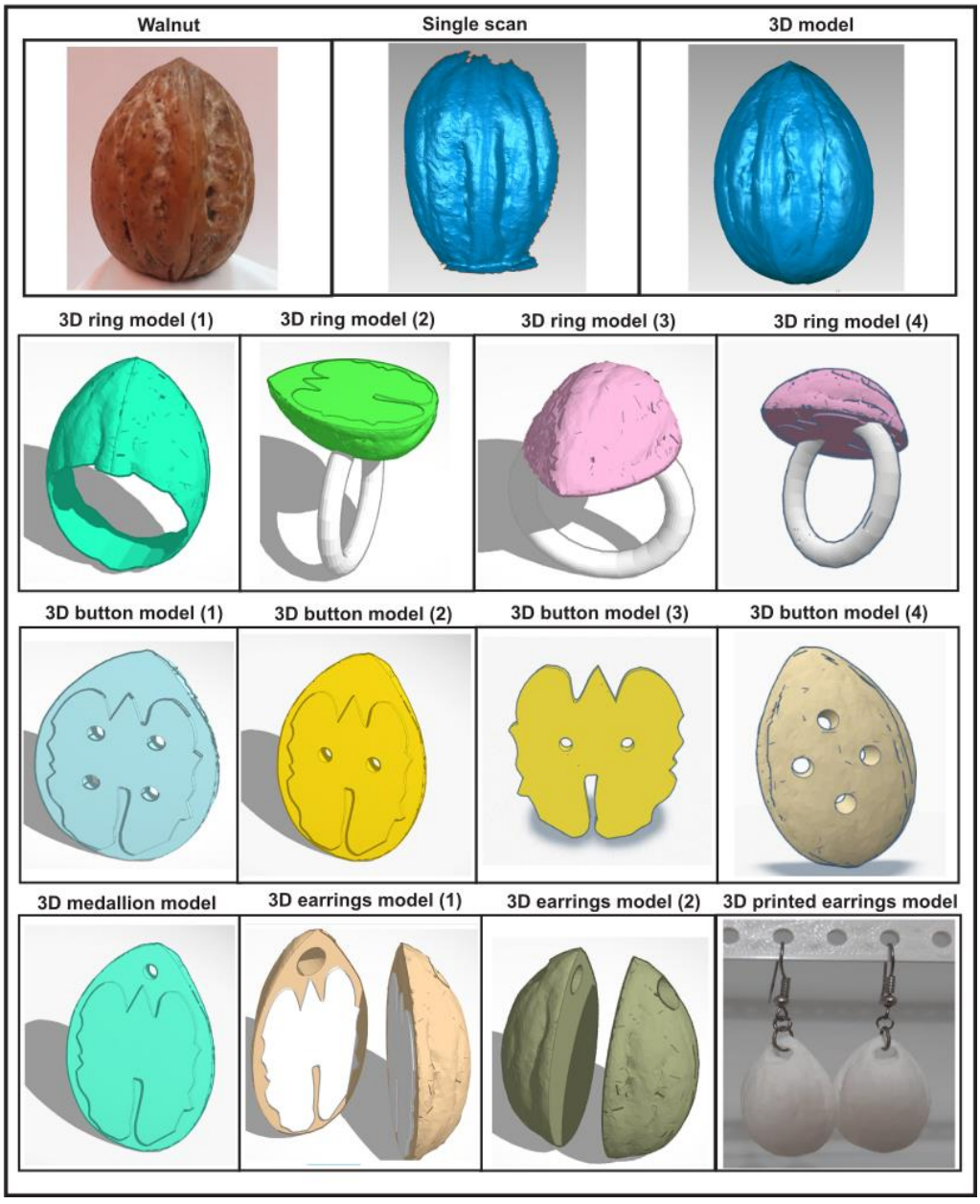

Figure 6. From product digitalization used for designing jewelery and accessories to the final product taken through 3D printing technology.

6. Conclusions

The role of the Industry 4.0 in the fashion industry is obviously evident from production, merchandizing, retailing and customer. Implementation of advanced technology as some of the pillars of Industry 4.0 shows again the short time to realize fashion products, from concept to 3D model, by taking inspirations from various sources. The work presented here is part of a project to realize fashion products through advanced technologies. The cases of garments, jewelery and accessories presented here with all the steps from concept to production, as digitizing, 3D modelling, simulation and produced by additive manufacturing. Inspirations taken from nature are a great source of inspiration to create unique products at lower prices.

Reducing lead times, waste, and advantages to create, visualize and evaluate products at early stages of product creation are some of the advantages of these technologies as part of Industry 4.0 in the fashion industry. Product evaluation at early stages of creation contributes to sustainability in fashion industry. Virtual prototyping brings to the fashion industry as in other industrial sectors great advantages compared to traditional way of garment design. Innovative tools developed by companies are able to create a realistic presentation of virtual garment ensuring a better visualisation of product at early stages before its physical production. Companies should try to embrace this technology in their product development. As a result, additional skills are required for operators in this process in order to accelerate production and to be competitive on the market.

3D printing technology also known with the general name additive manufacturing brings great advantages for product creation with lower cost and the possibility to produce customised fashion products even with complex geometry, bringing again the advantages of these technologies as part of Industry 4.0 in the fashion industry. Using 3D printing technologies for jewellery production seems to have great advantages.

References

[1] Gilchrist A 2016 Introducing Industry 4.0 *Industry 4.0* (Berkeley, CA: Apress) pp 195-215
[2] Ribiero da Silva E H D, Angelis J, Pinheiro de Lima E 2019 In pursuit of Digital Manifacturing *Procedia Manufacturing* **28** pp 63-69 https://doi.org/10.1016/j.promfg.2018.12.011
[3] Karell E, Niinimäki K 2020 A Mixed-Method Study of Design Practices and Designers' Roles in Sustainable-Minded Clothing Companies *Sustainability* **12** (11) 4680 https://doi.org/10.3390/su12114680
[4] Kwon Y M, Lee Y, Kim S J 2017 Case study on 3D printing education in fashion design coursework *Fash Text* **4** (26) https://doi.org/10.1186/s40691-017-0111-3
[5] Sun L, Zhao L 2017 Envisioning the era of 3D printing: a conceptual model for the fashion industry *Fash Text* **4 (**25) https://doi.org/10.1186/s40691-017-0110-4
[6] Chong S, Pan G T, Chin J, Show P L, Yang T C K, Huang C M 2018 Integration of 3D Printing and Industry 4.0 into Engineering Teaching *Sustainability* **10** (11) 3960 https://doi.org/10.3390/su10113960
[7] Madsen D Ø 2019 The Emergence and Rise of Industry 4.0 Viewed through the Lens of Management Fashion Theory *Adm. Sci.* **9** (3) 71 https://doi.org/10.3390/admsci9030071
[8] Gazzola P, Pavione E, Pezzetti R, Grechi D 2020 Trends in the Fashion Industry. The Perception of Sustainability and Circular Economy: A Gender/Generation Quantitative Approach *Sustainability* **12** (7) 2809 https://doi.org/10.3390/su12072809
[9] Paritala P K, Manchikatla S, Yarlagadda P 2017 Digital Manufacturing- ApplicationsPast, Current, and Future Trends *Procedia Engineering* **174** pp 982-991
[10] Nadasbaş S E, Çileroğlu B 2016 The use of 3D printers in fashion design for different models and sizes *Global Fashion*
[11] Sitotaw D B, Ahrendt D, Kyosev Y, Kabish K A 2020 Additive Manufacturing and Textiles - State of the Art *Appl. Sci.* **10** (15) 5033 https://doi.org/10.3390/app10155033
[12] Fan Z, Meixner L 2020 3D Printing: A Guide for Decision-Makers *World Economic Forum, Geneva, Switzerland*
[13] Elmelegy N A 2017 3D Printing The Future of Innovative Shapes and Materials in Women Fashion Design *Eurasian Journal of Analytical Chemistry* **13** (3)

[14] Bertola P and Teunissen J 2018 Fashion 4.0. Innovating fashion industry through digital transformation *Research Journal of Textile and Apparel* **22** (4) pp 352-369 https://doi.org/10.1108/RJTA-03-2018-002
[15] Papachristou E, Bilalis N 2015 How to Integrate Recent Development in Technology with Digital Prototype *Marmara Journal of Pure and Applied Sciences* special issue 1 pp 32-39
[16] Papachristou E, Kyratsis P, Bilalis N 2019 A Comparative Study of Open-Source and Licensed CAD Software to Support Garment Development Learning *Machines* **7** (2) 30 https://doi.org/10.3390/machines7020030
[17] Kyratsis P, Kakoulis K, Markopoulos A P 2020 Advances in CAD/CAM/CAE Technologies *Machines* **8** (1) 13 https://doi.org/10.3390/machines8010013
[18] Gunal M M 2019 Simulation and the Fourth Industrial Revolution In: Gunal M. (eds) *Simulation for Industry 4.0* (Cham: Springer, Springer Series in Advanced Manufacturing) https://doi.org/10.1007/978-3-030-04137-3_1
[19] Carulli M, Vitali A, Caruso G, Bordegoni M, Rizzi C, Cugini U 2017 ICT Technology for Innovating the Garment Design Process in Fashion Industry. In: Chakrabarti A., Chakrabarti D. (eds) Research into Design for Communities volume 1 ICoRD 2017 *Smart Innovation, Systems and Technologies* **65** (Singapore: Springer) https://doi.org/10.1007/978-981-10-3518-0_46
[20] Lin F, Wong M C, Ge M 2018 Development of the digita lmodel of the jewellery production process for resourceoptimisation and prediction *HKIE Transactions* **25** (4) pp 229-236
[21] Matos J, Almeida H A, Ascenso R M T, Novo C, Freire M 2016 Development of a sustainable toothbrush with the aid of additive manufacturing technologies. In Moreira da Silva F, Bártolo HM, Bártolo P, Almendra R, Roseta F, Almeida HA, et al., editors. *Challenges for Technology Innovation: An Agenda for the Future* (Lisbon, Portugal: Taylor & Fransis Group) pp 45-50
[22] Kielarova S W, Pradujphongphet P, Bohez E L J 2015 New Interactive-Generative Design System: Hybrid of Shape Grammar and Evolutionary Design - An Application of Jewelry Design. In: *Advances in Swarm and Computational Intelligence ICSI 2015 Lecture Notes in Computer Science*
[23] Demarco F, Bertacchini F, Scuro C, Bilotta E, Pantano P 2020 Algorithms for Jewelry Industry 4.0. In: Sergeyev Y., Kvasov D. (eds) *Numerical Computations: Theory and Algorithms NUMTA 2019 Lecture Notes in Computer Science* **11973** (Cham: Springer) https://doi.org/10.1007/978-3-030-39081-5_37
[24] Mpofu T P, Mawere C, Mukosera M 2014 The Impact and Application of 3D Printing Technology *International Journal of Science and Research* **3** (6) pp 2148-52