CIRCULAR ECONOMY THROUGH CUSTOMISED 3D PRINTED PRODUCTS: A CASE OF SOUVENIR

Lazaros Firtkiadis, Prodromos Minaoglou, Athanasios Manavis, Kyriaki Aidinli, Nikolaos Efkolidis
University of Western Macedonia, Department of Product and Systems Design Engineering, Kozani, Greece

Abstract: *Nowadays, the circular economy model is basically built on the efficient use of resources and the maximization of the product's lifetime as long as possible, by recovering, reusing and recycling existing materials and products. Comparing circular economy with the new trend of customized products, there is an opportunity for the production of personalized products with less associated environmental costs. As a key factor can be considered the 3D printing technology, which is already widely accessible, offering customisable possibilities without expensive tooling based on individual specifications. Furthermore, the opportunity for recycling and degradation of different plastic materials and the creation of a filament for 3D printers has large impact on the product life cycle. The aim of this study is to highlight the management of recyclable plastic by creating new customized products. Souvenir industry has been chosen as a representative example which covers a big number of different products offering simultaneously a mass customized character.*

Key words: Circular Economy, Customized Products, 3D Printing, Souvenir

1. INTRODUCTION

The circular economy as a part of sustainability has as main target to protect the environment, improve economics, and promote social justice. Circular economy seeks to completely improve resource efficiency by reducing the waste and keeping materials, products, and services in circulation for as long possible. Nowadays, It is one of the most powerful concept to address the climate crisis, and material recovery. The whole concept is based on the replacement of the current linear model of 'take – make – waste' by the circular model of 'make –use -recycle'. The development of new processes and technologies creates opportunities for changing manufacturing activities such as the supply and flow of materials with many possible sustainability benefits (Gebler, Schoot Uiterkamp & Visser, 2014). Those changes promote Circular Economy by improving the efficiency of the resources. As a representative example can be considered the technology of 3D printing, also known as additive manufacturing.
Nowadays, different technologies permit objects to be scanned, manipulated into files and then to be printed (Kietzmann, Pitt & Berthon, 2015). The related technology is not anymore so expensive and specialized, conversely has become accessible, both in price and the use with extremely user-friendly interface simple and safe enough to use in a domestic setting. The advantage of the technology use is that it generates opportunities to produce customized products. In the case of souvenir visitors are able to adapt, modify or transform existing souvenirs or to choose new one, totally different from the existing. As the technology is becoming more and more available, it may be possible to consider souvenirs as dynamic objects which involve self-development and creativity by developing customized objects rather than mass produced items.

2. LITERATURE SURVEY

This technology of 3d printing as opposed to the other manufacturing methodologies, which are based to subtractive methods, is a process of creating a three-dimensional models layer-by-layer using CAD systems. This additive process whereby layers of material are built up to create a 3D part has as a result to create less material wastage. 3D printing process can use a variety of 3D printing materials, including thermoplastics, metals, resins and ceramics building models with different processes such as binder jetting, direct energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination and VAT polymerization (Izdebska-Podsiadły, 2022). While the other manufacturing techniques are still more suitable for high volume and much faster mass production, 3D printers becoming faster and faster allowing to work on larger scale production. Furthermore, the low cost of 3d printers promotes the use of

this technology into homes, universities and different companies. The continuously development of 3d printing enhanced the research for the controlling mechanical properties of 3D printed parts (Kyratsis & Tzetzis, 2018; Meretis et al., 2022) such as tensile yield strength, modulus of elasticity, shear yield strength, hardness etc.. Furthermore, a comparison between virgin material of filaments and recycled material showed that both filaments are almost similar to the mechanical properties of 3D printed samples. This fact promotes additional development in recycling 3D printed filament (Mikula et al., 2021; Lanzotti et al., 2019), mainly by managing to obtain recycled filament from waste and used it for the creation of samples and prototypes. Despeisse et al. (2017) proposed a research agenda to determine enablers and barriers for 3D printing to achieve a circular economy. They explored how can a more distributed manufacturing system based on 3D printing create a circular economy of closed-loop material flows and what are the barriers to a circular 3D printing economy. They concluded that the characteristics of 3D printing align well with sustainability and circularity principles and hold significant promise for moving society in a more sustainable direction. The implementation of 3D printing into the industrial system delivers triple bottom line benefits. Clemon & Zohdi (2018) developed a framework that identifies the stress contributions, and their variation, to reduce product development time and costs, which could greatly speed up material recycling and reuse for improved infrastructure materials, low-cost 3D printer filament, and reduced waste towards a more circular economy.
Souvenir industry covers a huge number of different samples that can be created. Souvenir is an object related to memories and psychological connections which owner has from a past experience. As souvenir can be considered any object that purchased and transported home by any traveler and offers him the opportunity to transform the intangible moments and feelings during a visit into tangible memories. Souvenirs are the tangible reminders of unique moments and occasions. Souvenirs are an important part of the tourist economy and many people are directly and indirectly involved in their production, distribution and sale with most of them be related with local produced objects with traditional methods. As 3D printing is a continuously developing technology, 3d printed samples like souvenirs can be considered as dynamic objects which involve visitors for the development of customized objects. Anastasiadou & Vettese (2019) proposed the 3D printed souvenirs as the new type of souvenir as they examined visitor preferences and managers views on 3D printed souvenirs that were mass produced but individualized within a heritage retail environment. The visitors were able to interact with the digital making process. The findings suggest that while there is interest in designing and personalizing souvenirs using new technologies, there are also intellectual and ethical challenges which need to be addressed. Qiuxia, Rahman & Wenhong (2022) examine the development and strategies of souvenir design and its future directions. They reported the outcomes of a thematic review analysis examining souvenir research from a design perspective, addressing the knowledge and methods required in practice-based souvenir design. The result suggests among others that future research trends in souvenir design should focus on customer-oriented product design and sustainability for promoting local culture and economies.

3. PROPOSED METHODOLOGY

This study is based on the replacement of a portion of virgin PLA by a recycled HDPE (High Density Polyethylene) from used bottle caps to produce 3D printing samples. Three different machines were used, a shredder, a dryer, and an extruder with a puller. In the beginning the bottle caps were cleaned as it is critical that the shredding is done with clean HDPE without any contaminants. The cleaning was done with hot water and cleaning fluid for deleting any labels that caps may have. When the bottles were fully cleaned, they were left to dry. Then, the caps were placed into a shredder (SHR3D-IT shredder), to converted into small granules. Shredder must be cleaned properly in order to not contain any old material from previous use. Contaminated granules with other materials may give bad results in the final filament. The next step is the elimination of any moisture complication that may occur within a polymer. Moisture can affect seriously the quality of the produced 3D printing filament. For this reason, we used the AIRID polymer dryer (approx. 50°C inside the chamber) where the amount of the granules dried for three hours improving with this way the properties of the produced material by the elimination of moisture. After the mix of 40% of recycled HDPE and 60% pure PLA the amount of the material placed to the COMPOSER Series 450 filament maker from 3Devo. 3DEvo's extrusion machine allow to transform plastic pellets (new or recycled) by warming and melting the granules pushing them in order to extrude filament with 1.75mm diameter in the temperature of 220-230oC into a quality 3D printing filament. Figure 1 illustrates the steps of the described process.

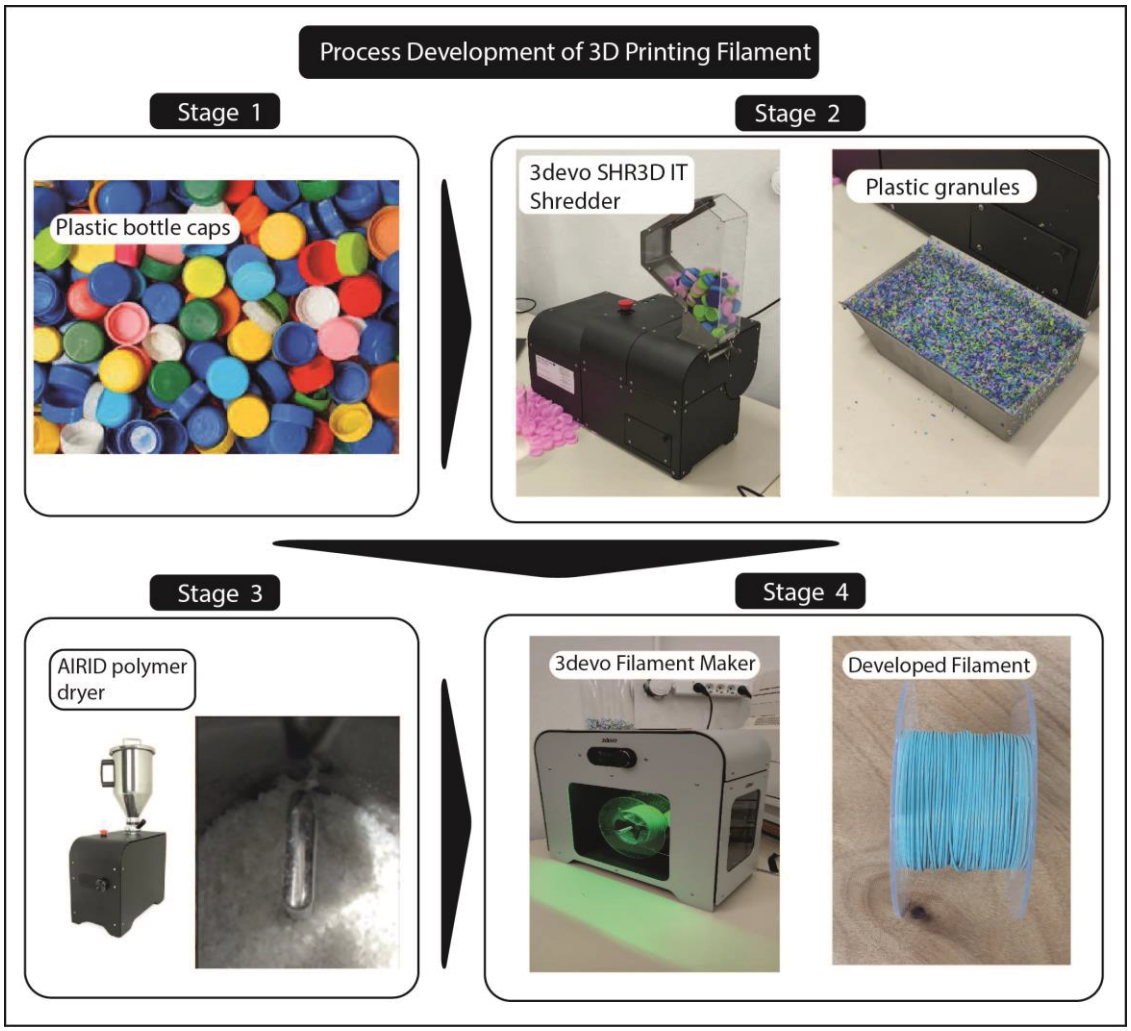

Figure 1: Manufacturing process 3D printing filament.

4. CASE STUDIES

According to User Centered Design (UCD) process users are at the center of the product design. User's requirements, objectives, and feedback are now necessary in the design process where the satisfaction of the user's needs and wants considered as a priority. Every decision during the process is assessed according to whether or not it delivers value to the users. Furthermore, User-centered design gives a way of adding an emotional impact into the products. Based upon technology is now feasible the user involvement with a limited experience in the editing and creation of designs and customized parts which are difficult or impossible for traditional methods to produce.

3D scanning technology rebuild all the necessary information about physical objects in three dimensions in a digitally world with precise dimensions. The scanned data can be used for the analysis, design and development. This technology offers a lot of opportunities for customization. There are many facilities that allow users to choose or scan a 3D model and take back their own 3D printed copy model. The combination of 3D scanning and 3D printing technology can produce actual object archetype without the need of conventional techniques. Products of different sizes can be 3D scanned and be printed with the exact dimensions. The development of any prototype can be easily possible. 3d scanning done with the help of DAVID SLS-3 scanner. DAVID SLS-3 scanner uses the structured light 3D scanning technology generating fast colored 3D scans with scan size between 60-500 mm. The equipment includes also a HD Video projector with a large focus range and stable glass calibration panels. The 3D scans can be exported into common 3D file formats for processing in other applications such as 3D printing, archeology heritage, works of art, computer animations etc.

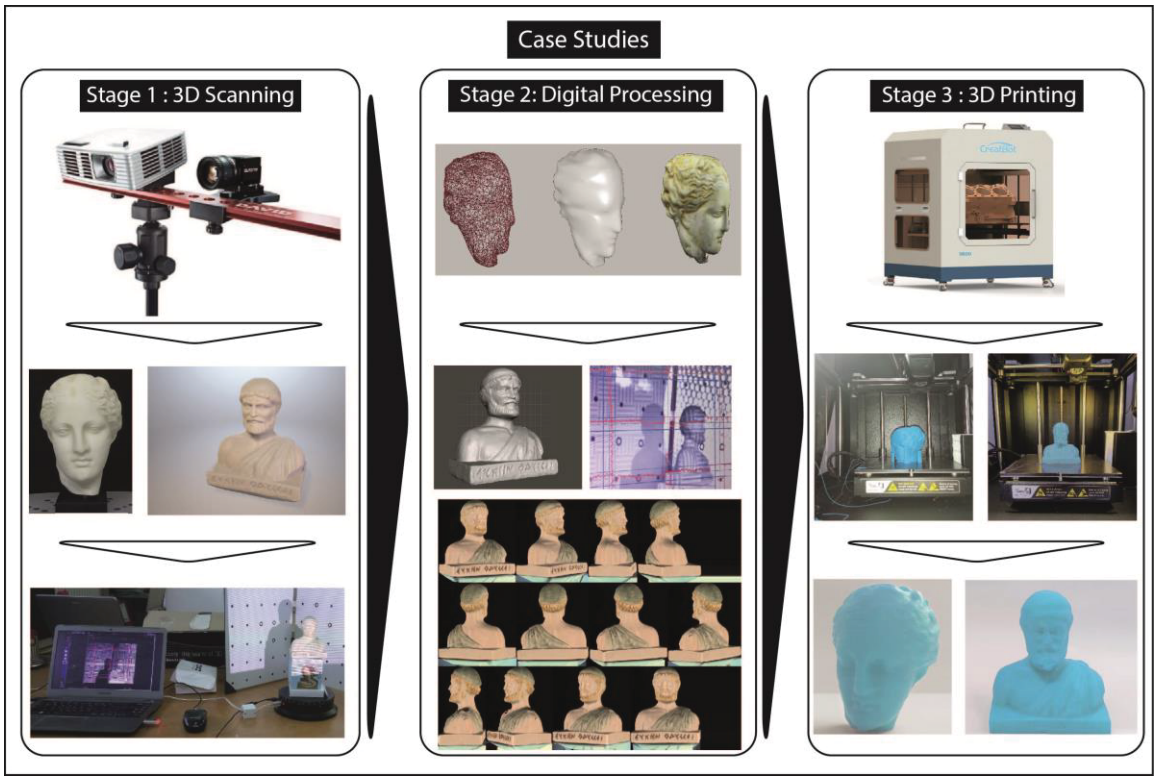

Figure 2: Case studies development.

A prototype design tool Meshmixer Autodesk, Inc. software used for the creation of 3D high-resolution dynamic triangle meshes and for checking the models for printability and orientation. This kind of tool efficiently ensure the quality of 3D models by recognizing the issues before it proceeds to print.
A Creatbot D600Pro 3D printer was used for the creation of souvenirs. Its feeding system support high-speed printing, accuracy can reach high to 0.05mm and Nozzle Temperature Up To 420 ℃. There are two extrudesr with the one of them equipped with 260°C hotend, and It is able to print with PLA, ABS, Nylon, Carbon fiber, etc. and the other one equipped with 420°C hotend which is made of martensite steel is able to print high performance materials. In this study, as representative examples have been developed products like the 3d printed statue of Hygeia, an ancient Greek goddess who ensuring good health for body and soul and a statue of 'Odysseus the ingenious' a king of ancient Ithaca, Greece (Figure 2).

5. CONCLUSIONS

Circular economy is built in the renewal of the components and materials. It manages the waste as a part in the manufacturing process so decreases the production of the pure materials. Materials, parts and components are used to regenerate other products as can be repaired, reused, reconditioned, and finally recycled. Nowadays, the matter of plastic recycling has become one of the most important concerns of environmental protection and waste management. The waste materials as a source of materials for filament production for 3D printing is beneficial both economically and environmentally. They reduce material costs, CO2 emissions and energy consumption. Recycling plastic waste has a great potential and benefits but needs investments and consumer knowledge. The On-demand 3D printing can offer a database of souvenirs that can be send by e-mail and then be created by 3D Printers. The no need of transportation or standard production methods the object carbon footprint is reduced to the minimum. As tourism industry grows souvenirs are becoming critical for promoting country's image and culture. This study proposed the way some of souvenirs could be manufactured with the aim of new technologies reducing their impact on the environment. On-demand 3D printing also saves on tooling costs and provides an advanced time-to-market.

6. REFERENCES

Anastasiadou, C. & Vettese, S. (2019) From souvenirs to 3D printed souvenirs. Exploring the capabilities of additive manufacturing technologies in (re)-framing tourist souvenirs. *Tourism Management*. 71, 428-442. Available from: doi: 10.1016/j.tourman.2018.10.032

Clemon, L. M. & Zohdi, T. I. (2018) On the tolerable limits of granulated recycled material additives to maintain structural integrity. *Construction and Building Materials*. 167, 846-852. Available from: doi: 10.1016/j.conbuildmat.2018.02.099

Despeisse, M., Baumers, M., Brown, P., Charnley, F., Ford, S. J., Garmulewicz, A., Knowles, S., Minshall, L. Mortara, T. H. W., Reed-Tsochas, F. P. & Rowley, J. (2017) Unlocking value for a circular economy through 3D printing: A research agenda. *Technological Forecasting and Social Change*. 115, 75-84. Available from: doi: 10.1016/j.techfore.2016.09.021

Gebler M., Schoot Uiterkamp A. J. M. & Visser C. (2014) A global sustainability perspective on 3D printing technologies. *Energy Polic*y. 74, 158-167. Available from: doi: 10.1016/j.enpol.2014.08.033

Izdebska-Podsiadły, J. (2022) Chapter 3 - Classification of 3D printing methods. In: Izdebska-Podsiadły, J. (ed.) *Polymers for 3D Printing*. Amsterdam, Elsevier, pp. 23-34. Available from: doi: 10.1016/B978-0-12-818311-3.00009-4

Kietzmann, J., Pitt, L. & Berthon, P. (2015) Disruptions, decisions, and destinations: Enter the age of 3-D printing and additive manufacturing. *Business Horizons*. 58 (2), 209–215.

Kyratsis P. & Tzetzis D. (2018) Investigation of the mechanical properties of acrylonitrile butadiene styrene (ABS) - Nanosilica reinforced nanocomposites for fused filament fabrication (FFF) 3D printing. In: *7th International Conference on Advanced Materials and Structures, AMS18*, *28-31 March 2018, Timisoara, Romania*. Bristol, IOP Publishing. Available from: doi: 10.1088/1757-899x/416/1/012086

Lanzotti, A., Martorelli, M., Maietta, S., Gerbino, S., Penta, F. & Gloria, A. (2019) A comparison between mechanical properties of specimens 3D printed with virgin and recycled PLA. *Procedia CIRP*. 79, 143-146. Available from: doi: 10.1016/j.procir.2019.02.030

Meretis E., Tzimtzimis E., Tsongas K., Kyratsis P. & Tzetzis D. (2022) Fabrication and Nanomechanical Testing of Conductive Nanocomposites Filaments for FFF 3D Printing: development of a 3D printed emergency stop button. *Academic Journal of Manufacturing Engineering.* 20 (1), 47-55.

Mikula, K., Skrzypczak, D., Izydorczyk, G., Warchoł, J., Moustakas, K., Chojnacka, K. & Witek-Krowiak, A. (2021) 3D printing filament as a second life of waste plastics—a review. *Environmental Science and Pollution Research*. 28, 12321–12333. Available from: doi: 10.1007/s11356-020-10657-8

Qiuxia, Z., Rahman A. R. A. & Wenhong H. (2022) A thematic review on souvenirs from design perspective publications from 2012–2022: analysis of trends for future studies. *Cogent Arts & Humanities*. 9 (1), Available from: doi: 10.1080/23311983.2022.2100129