UNIVERSIDADE DA BEIRA INTERIOR

3D printing and its possible role in the sustainability of the fashion market

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Dissertação para obtenção do Grau de Mestre em

Design de Moda

(2º ciclo de estudos)

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Covilhã, Junho de 2023

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Dedication

Professor Lucas that guided me through the first steps of this journey.

He was an excellent teacher, beloved by all and I this is not something I say lightly. He had been sick for a while, yet he braved through the pain to brighten his student's lives, his students who he esteemed so, he gave us strength, he gave us support and he gave us guidance, despite everything he was going through. I have heard a lot in my life, as I'm sure have you readers, about strength. Well, I believe Professor Lucas was the embodiment of it. He was not well, but still he involved us, students, in childlike wonder when he spoke of the beautiful cherry blossoms that has bloomed so well that year.

He was, to this day, the best teacher, the best mentor I could have asked for and I am very thankful to have been his student.

I am not the most spiritual person, but I hope he is watching over us and I hope he sees me complete this journey.

Acknowledgements

I want to thank my dissertation advisor Professor Gouveia and co-advisor Professor Guerreiro, as I could not have completed this dissertation without their help and support.

Summary

A moda, como indústria, sempre aspirou alcançar o novo e o empolgante. O mercado precisa procurar maneiras de manter a relevância diante da sociedade em constante mudança para a qual cria. Nos últimos anos, esse aspeto do mercado tem vindo a ganhar muita importância, pois houve uma mudança devido à característica imediata do "agora" que a globalização proporciona. A nova proximidade, vista por todo o mundo, permitiu que a instantaneidade da comunicação transformasse o consumidor em um membro ativo do mercado, e não passivo. O consumidor agora tem uma voz, uma voz que é ouvida pelas maiores marcas de moda mundiais. Ele pode e irá usar essa influência para obter benefícios. As marcas estão a começar a perceber que novas tecnologias, como a Internet, oferecem esse mesmo poder aos seus consumidores e estão cada vez mais desesperadas para encontrar novas maneiras de tirar vantagem dessa flagrante mudança de poder, fazendo com que a era da informação funcione a seu favor, em vez de se pegarem aos tradicionalismos.

Com essa brilhante conclusão em mente, as marcas de moda estão a começar a virar as suas estratégias de marketing de forma a envolver esse novo tipo de consumidor inteligente. Este consumidor nasceu com informação na ponta dos dedos, tem moral, ideais, causas pelas quais luta e um sentido individualizado de justiça. Portanto, esse consumidor deseja que as marcas às quais ele compra sirvam esses mesmos princípios. Exigindo que um conjunto de éticas seja cumprido, por exemplo: *cruelty free, vegan, fur free*, sustentável, honesto etc.

A indústria da moda tem aqui a oportunidade de reunir a sua necessidade de inovação e a necessidade do novo consumidor por um design mais ético, tentando combinar novas tecnologias com o benefício de fazer o possível para salvar o mundo no processo. A meu ver a tecnologia 3D tem o potencial de fazer isso.

É com isto em mente que esta dissertação se desenvolveu na direção do projeto pratico de utilização da tecnologia de impressão 3D. Sendo que o objetivo da proposta experimental consistiu em testar o quão possível seria a introdução da impressão 3D no quotidiano da produção de moda, através da concretização de alguns protótipos. Para além disso, a impressão 3D tem a possibilidade de revolucionar os métodos tradicionais de fabrico há muito associados com a indústria da moda.

Palavras Chave: *Moda - Evolução - Impressão 3D - Tecnologia - Sustentabilidade*

Abstract

Fashion, as an industry, has always strived for the new and exciting. The market needs to seek ways to keep its relevance face the ever-changing society it creates for. Over the last few years, that aspect of the market has been gaining a lot of importance, as there has been a shift, due to the characteristic, immediate "now" that globalization provides. The newfound closeness, seen throughout the entire world, has allowed the instantaneousness of communication to turn the consumer into an active member of the market rather than a passive one. The consumer now has a voice that is heard by the biggest fashion brands out there. He can and will use that influence for its benefit. Brands are realizing the new found power technology, like the internet, gave to its consumers and are more and more desperate to find new ways of taking advantage of that blatant power shift, making the age of information work in their favor, instead of holding on to traditionalism.

With that brilliant realization in mind, fashion brands are starting to market to a new type of smart consumer. This consumer was born with information on his fingertips, he has morals, ideals, causes he fights for and a individualized sense of justice. This consumer, therefore, wants the brands he purchases from to serve those same principles. Demanding a set of ethics to be met eg: cruelty free, vegan, fur free, sustainable, honest, etc.

The fashion industry has an opportunity here to pull together it's need for innovation and its new consumer's need for a more ethical design, by trying to combine new technology with the benefit of doing their best to save the world in the process. I believe 3D technology has the potential of doing that.

It is with this in mind that this dissertation developed towards the practical project of utilizing 3D printing technology. Since the objective of the experimental proposal came to be to test how possible the introduction of 3D printing in the daily fashion production would be through the creation of prototypes. Throughout this dissertation there are demonstrations of great achievements that demonstrate that 3D printing has the possibility of revolutionizing traditional manufacturing methods, long associated with the fashion industry.

Key Words: *Fashion - Evolution - 3D Printing - Technology - Sustainability*

Extended Summary

Segundo o jornal *Science* (2015), entre cinco a treze milhões de toneladas de plástico acabam por aparecer nos oceanos todos os anos. Dados lançados por *National Oceanic Atmosferical Administration* (NOAA), sugerem que cerca de 80% da poluição que se encontra no oceano provém de escoamento, sugerindo que a maior forma de poluição da água de todo o planeta não resulta necessariamente do plástico. Porém a constatação desse facto não invalida a ameaça da poluição do plástico e esta é, a meu ver, um problema que a indústria da moda pode acolher e melhorar.

O plástico à deriva dos oceanos pode ser considerado um recurso ao qual a sua reutilização deve ser imprescindível, já que a matéria-prima intocada do planeta está em esgotamento e a indústria da moda, desde a democratização da moda que aconteceu devido à revolução industrial, requer um ritmo extremamente elevado de criação de design. A criação do conceito de *fast fashion* proporcionou ao consumidor comum a oportunidade de usufruir de produtos que anteriormente este não conseguia adquirir devido a fraco poder financeiro. Dai a democratização do produto do vestuário proporcionou ao consumidor comum a oportunidade de conseguir o direito à moda, que antes da revolução industrial era um privilégio que abrangia somente as classes mais abastadas.

A democratização de tais bens, apesar de ser vista como algo positivo, veio também com a sua quota parte de aspetos negativos. Um desses aspetos foi o excesso de consumo que se deu devido ao elevado nível de produção. No seculo XVIII e durante a maioria do seculo XIX isto não impôs qualquer problema, porém anos e anos de consumo desnecessário levaram a que esse excesso se revelasse um problema grave, pois os recursos do planeta Terra são finitos. A produção elevada levou ao esgotamento de matéria, e o consumo excessivo, rápido e agressivo levou a que o ciclo de vida dos produtos diminuísse em muito, isto, por sua vez fez com que a quantidade de bens descartados aumentasse e, daí, deu-se um aumento na poluição.

No decorrer desta dissertação haverá uma análise sobre a possibilidade da impressão 3D ser a solução desses problemas no que toca à indústria da moda. A impressão 3D está, correntemente, a ser analisada como uma forma sustentável de produção de bens. Este é um processo de criação que tem a capacidade de ter muito pouco desperdício, já que o único processo de criação físico, ou seja, para alem do CAD, contém apenas o processo de impressão. Para além disso a possibilidade de disponibilizar online, para que o consumidor imprima o produto em casa, elimina desde logo a necessidade de recorrer a transportes para

o *shipping* do produto, contribuindo para diminuir o uso de combustíveis fosseis, que são, obviamente, corrosivos para o meio ambiente.

As marcas começaram a usar todos os tipos de dispositivos de conectividade para se tornarem mais disponíveis, mais humanizadas aos olhos de seus clientes, usando os media sociais como um meio de se tornarem relacionáveis com todo o tipo de consumidor para qual vendem. Elas começaram a ser extremamente ativas e pessoais em *apps* como o Facebook, o Twitter e o Instagram, e começaram a promover os seus produtos por meio de *Online Influencers*, que são celebridades *on-line* que mantêm relações com o público muito mais próximas do que as celebridades normais, aparecendo perante a sua audiência mais como amigos do que pessoas famosas. Essa proximidade é exatamente o que as marcas precisam atualmente para sobreviver. Isso e uma boa bússola moral.

Da mesma forma que a geração da informação pode criar uma marca, eles podem boicotá-la com a mesma facilidade. Pode-se argumentar que, com o bom, também apareceu o mau e o feio. Embora isso possa depender da perspetiva, pois isso faz com que as marcas agora sejam quase que pressionadas pelas massas para se manterem honestas e fiéis ao que afirmam ser. As informações prontamente disponíveis servem a propósito de responsabilizar a marca por seus erros. Indiscutivelmente ruim para a marca (se for apanhado no meio da polêmica), bom para a ética.

Nesta dissertação existe também uma parte pratica, na qual foram exploradas as reais possibilidades de implementação da impressão 3D na indústria da moda, bem como a dificuldade do processo em termos de acessibilidade do consumidor comum, replicando o quão intuitivo seria executar o processo numa impressora criada para uso pessoal. Isto porque construir qualquer peça pelo método da impressão 3D é definitivamente mais simples quando falamos de indústrias de grande poder económico, com equipas de engenheiros à disposição.

Após vários testes numa impressora PruzaSlicer, uma impressora de categoria Material Extrusion de uso pessoal, ficou claro que, embora haja uma curva de aprendizagem e um nível de habilidade e *know how* associados à capacidade de produção deste método, não é uma adaptação impossível.

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Acronyms List

3D – Three Dimensional

AM – Addictive Manufacturing

CAD – Computer Aided Design

UV – Ultraviolet

ASTM – American Society for Testing and Materials

SLA - Stereolithography

DPL – Digital Light Processing

CLIP – Continuous Liquid Interface Production

LED – Light Emitting Diode

MIT – Massachusetts Institute of Technology

FDM – Fused Deposition Modeling

CAM – Computer Aided Manufacturing

FFF – Fused Filament Fabrication

MJF – Multi Jet Fusion

SLS – Selective Laser Sintering

DMLS – Direct Metal Laser Sintering

DDM – Direct Digital Manufacturing

MET – Metropolitan Museum of Art

STL - Standard Tessellation Language

USD – United States' Dollars

Chapter 1 - Introduction

1.1 Framework and Research Questions

The word fashion has always been intertwined with the concept of *avant-garde* and it is in a way forever connected with the human being, as it is used as a second skin.

Technology has the power of connecting people in a way, it makes living in the 21st century practical, easy and comfortable. It has evolved to serve the human being in a fast-paced modern way of living, enabling them to adapt to a way of living very different from the previous generations. It is no secret that the newer generations are often accused of sailing through a life online instead of truly living it, but every generation comes with its own set of challenges and that kind of thought can pose to be very patronizing.

Connectivity is, at first look, something amazing. The world turned small and convenient thanks, in no small part, to technology. The internet being a great example of that, but not the only one (Lee, J & Kim, D. & Ryoo, H. & Shin, B., 2016). Depending on how one understands the definition of technology, wearable technology, or wearables, have been present in our world for as long as the 13th century (Sawant, 2022), when the first eyeglasses where invented (Buensuceso, 2021). Since then, technology has been a part of our lives, existing among us to promote an easy, although complex, lifestyle. And one can argue that as technology has evolved to connect the world, so it has done with fashion. Fashion is, at its core definition, a wearable and the wearable has been in turn intrinsically coupled with the concept of fashion since the very beginning, for better or for worse. This happens due to the very nature of the wearable, as it is meant to be worn as close as possible to the wearer in order to attempt to make their life a tad bit easier (Lee & Kim & Ryoo & Shin, 2016).

The way wearable technology has been evolving, has integrated, intentionally or not, the Internet of Things, which is the way almost every object we use daily is, to put it in simple terms, connected through data on a global scale (Mukhopadhyay & Suryadevara, 2014). This has been serving a great many purposes including, but not limited to the evolution of communication. One may argue that the connectivity of data is somewhat dangerous, as the human race is starting to trade its much-appreciated freedom, for relative desire of comfort. As headlines after headlines of hacker attacks pop up (Rose & Eldridge & Chapin, 2015), we could certainly start to wonder if we, as a species, may have become passive and lazy in

delivering our security to the hands of a third person, but wishing otherwise at this point may be hindering the process of evolution.

The market not only knows that as it has been catering to that. Therefore, as an industry that prides itself on keeping up with the latest trends, the fashion industry has been trying its hardest to keep up. Examples of this are being found everywhere, with brands such as Burberry who, together with apple, created an app that changes people's environments with specific drawings from the brand, created by artist Danny Sagra (Hendriksz, 2017). We can also see that effect in brands like Kate Spade that partnered with fossil to make a smartwatch (O'Shea, 2018) and with Everpurse to make a bag that capable of charging iPhones (Fukushima, 2015).

Technology is the future, at this point it would be foolish to think otherwise. So, in the recent wave of awareness about the state we, the human race, left our planet, why not consider that changing the way we create product, using 3D technology, could be the path we need to follow in order to take responsibility for our future, while embarking in a more sustainable journey.

This dissertation comes from an idea that 3D printing might just be one of the possible answers for the problem we are all facing whether we want to or not (Greeninger & Pasricha, 2018). The lifestyle we have been living has come back to haunt us with a spectacular show of strength. Blistering cold has been felt in several parts of the United States of America, endangering people, animals, entire ecosystems and bringing the promise of damaged power grids along. All of this is being discussed and debated as to whether it has, or not, any connection to the climate crisis we have been expecting for a while now (Canon, 2022). In Europe, we can see quite the opposite happening in a few countries. In Poland, a notorious cold country may I add, recorded temperatures around 18ºC on the first day of the year 2023, in the city of Warsaw. While in Northern Spain temperatures around 24ºC were recorded on that same day (Meredith, 2023).

While repairs must be made in order to ensure that the human race indeed has a future, the population if the more capitalist countries has grown accustomed to having a certain standard of living. I for one am not ready to pick up a shovel and walk around in rags, living off the grid and doing all the hard work necessary to be able to not rely on modern luxuries, although I do have much respect for the people who are strong enough to choose that lifestyle. Bearing that in mind I must believe that there are alternatives, middle grounds, compromises we can make that both ensure that we maintain said luxuries, but we don't destroy our home while doing it.

Of course, there are the traditional and often brought up methods such as reduce, reuse, recycle, but seeing as there is a great disparity between the emissions of the richest 1% and the rest of the population, I would guess that it is safe to say that we common folk have been gaslighted into believing that we are the problem, while industries run ramped producing way more than they would ever need and billionaires run around pretending like their insane lifestyles have no consequences at all (Ratcliff, 2022).

With all that being said and because I believe changing the way we produce may be a better alternative than actually convincing people to change the lifestyle they have grown accustomed to, 3D printing technologies might just have been in the backburner, prepared for their time to show just how versatile and limitless they are.

3D printing, although not very widespread, is earning its place in the world of fashion. There are designers out there that have realized the possibilities it employs and have strived to incorporate this technology into their design method. Maybe not in the most wearable way, with strange futuristic designs, but perhaps in the future we can strive for everyday wear using this technology.

A great example of the use of 3D printing in fashion would be Iris Van Herpen, the designer takes inspiration from everything she finds interesting around her, from the shapes of the water to architectural structures. With this inspiration, she then strives for the creation of innovative pieces that look like they came straight from a dream of the future. Creative is certainly the word to describe her as she spends a lot of time and effort into bringing her designs into reality the design exactly how she first imagined them. For that purpose, she has a team that, with her, work hard to materialize her vision (Smelik, 2020). It is hard work and it requires a learning curve into processes that are not at all intuitive to traditionally educated fashion designers. (Sun & Zhao, 2017).

Image 1 – Iris Van Herpen's 2018 Spring Summer Collection, by Yannis Vlamos/ TU Delft [1]

The use of technologies like 3D printing has put her in the vanguard of fashion, allowing her to collaborate with names such as Bjork (Moss, 2019) and Lady Gaga (Veerman, 2020). Her forward-thinking techniques and out of the box thinking are not easy to come through, but she doesn't give up in her chase for what she believes can be accomplished, putting her, with all the merit, in the forefront of fashion creatively. She shows us that even though designing with 3D printing in mind may be hard, it is above all feasible and that is a very important mark, as this technology has proven to have sustainable qualities.

For starters, 3D printing has the capability of nurturing the new consumer's need for individuality and customization, in an easy, economic and, above all, sustainable way (D'Aveni, 2015). Using 3D printing can eliminate various processes from the act of creating a product, it involves only CAD creation and printing the product. That can eliminate a lot of waste (Jandyal & Chaturvedi & Wazir & Raina & Irfan & Haq 2021). There's more, 3D printing can be a useful tool in helping the democratic side of fashion. Everybody, nowadays, can own a 3D printer, so what does that mean? It means that designers may if they choose, sell their CAD design online and people may pay for it and print at home, which in turn reduces the need for shipping, therefore also annihilating the need for fossil fuels. That would be an unbelievable change, as, in the era of globalization, transportation around the world comes at a high cost, not only for the consumer, but the planet earth as well.

The last point, although, may come with its fair share of negatives as the "Journal of Industrial Ecology", of YALE University affirms that having the possibility of imprinting any product of your choosing, when you want, may be deteriorating to the environment, as excess of product would make sustainable efforts null and create as much waste as we are already making nowadays.

For that this analysis strives to purpose a solution: How about reusing existing plastics, and possibly other materials, in order to create new product? The industry of fashion is a ever changing giant, suggesting it slows down might be reaching to far, so recycling might be the way to keep the fashion industry from collapsing, as well as keeping our planet out of harm's way.

Various projects have already proved this to be possible. Adidas launched in 2017 one million sneakers made from plastic they cleaned from the ocean, in 2018 five million and they were projecting to sell eleven million in 2019 (Verry, 2019).

1.2 Objectives

This dissertation was made as an attempt to understand 3D printing, how it works, how it can be adjusted to fit into the fashion industry and just how sustainable is really the process of product development using 3D printing as a means of democratic production catered to the masses.

1.3 Methodology

Throughout this dissertation, a review of what has been accomplished has been elaborated, as well as an attempt to predict just how much can be done. There is no denying that there are limits to this technology, but the human being has proved, time and time again, to be nothing if not resourceful and, for that, I hold the belief that 3D printing is the undeniable future of, not only the fashion industry, but of every industry. The subtractive manufacturing way of creation is, besides archaic, wasteful and polluting.

3D printing is fresh, new and exciting for a industry that has been stuck in a method of production ancient and corrupt. Through analyzing and revising case studies, scientific articles, company sites and books, I plan to prove that this method is not only feasible, but a tremendous asset.

After reviewing the history and innerworkings of 3D printing and how it could or not be related to sustainability and the fashion industry, there was a discussion on whether a practical approach would be needed and the conclusion was that, in order for this dissertation to truly be complete, there was a need to experiment on whether it was possible or not to actually create a clothing garment on a small, not industrial in the slightest, Pruza printer.

1.4 Dissertation Structure

This dissertation is essentially spread into two different parts. The first part being a theoretical revision of literature, a dive into the academic perspective of what 3D printing

is, at its core, and what does it have to offer. It is an analysis on how well this process can blend into an industry it wasn't created for and that, frankly, struggles to adapt into. The second part strives to relate all that was previously speculated into reality, by attempting to create and illustrate what was studied during the process of writing this paper.

The first part is divided into 5 chapters, the first one being the introduction which strives to create a summary into what this dissertation is in its essence. The second chapter is comprehensive research into what 3D printing is, how it works and the types of printers in existence and the materials used, suited to each end product, suited to what the designer is effectively looking forward to bringing into existence.

The third chapter goes into what 3D printing can offer to the line of production in the fashion industry and into what has been already made, both in terms of clothing and accessories, examining how feasible it is to expect fashion designers to adhere to the manufacturing method. It also briefly approaches the legal troubles that a designer can face when embarking through this kind of process, namely how does intellectual property work when one's design is available online for purchase and how easy it would be to just hack blueprints, instead of buying them.

And lastly, the fourth chapter, on the other hand, questions just how sustainable is the creating process capable of being, questioning how low can 3D printing bring down the carbon print left behind by centuries of traditional manufacturing methods.

The second part is essentially practical. A corset and skirt were drawn and the goal was to see if it was possible to produce the pieces using a Pruza 3D printer.

Chapter 2 – 3D Printing

3D printing is a form of addictive manufacturing that consists of a very specific process of creation. It Is, as both names indicate, a technique that allows one to manufacture three dimensional solid objects through the action of layering of certain materials. The layers are successively added on top of each other to create the finished product, that's why it is called addictive manufacturing, due to its addictive process nature (Anonimous, 2019).

This process of manufacturing goods differs a lot from the previous, more traditional, methods. These archaic methods of fabrication are, in fact, the complete opposite from 3D printing as they, instead of adding product, subtract it, these methods cut or hollow out the desired form out of the original configuration of the material. It is exactly this blatant difference in method that allows the 3D printing creation to produce less waste, which, besides reducing significantly the cost of manufacturing, consciously enables sustainability (Jandyal & Chaturvedi & Wazir & Raina & Irfan & Haq 2021). Of course, the more traditional ways of manufacturing goods count with a fine set of advantages, such as speed of production (D'Aveni, 2015), however, when comparing the two methods as a whole, 3D printing certainly wins as the fastest process (Crump, 2014) as well as the most flexible, with a imbedded predispose to personalization and customization of goods (D'Aveni, 2015).

> The use of additive manufacturing technologies in different industries has increased substantially during the past years. Henry Ford introduced the moving assembly line that enabled mass production of identical products in the 20th century. Currently, additive manufacturing enables and facilitates production of moderate to mass quantities of products that can be customized individually. (Attaran 2017, p.677)

As of 1986, when Charles W. Hull patented the first ever stereolithograpgy 3D printer addictive manufacturing started out as a process best suited for prototyping, it was yet an expensive piece of tech and as such, not suitable for the market. But as technology evolved, so did 3D printing with it, becoming, in its own right, a production level technology (Matias & Rao, 2015). The growth of 3D printing methods in the mainstream of manufacturing had a slow rise, but as of recently, it has expanded exponentially through various markets. It is rare, now a days, to contemplate an industry that hasn't added the process of addictive manufacturing to their procedure.

The growth of this process has had such magnitude that Acumen Research and Consulting estimates that by 2026, the 3D printing market as a global affair will bring in 41 billion dollars, or approximately 37 billion euros (Acumen Research, 2019). Also, according to Lux Research the use of 3D printing techs is to grow by magnitude until 2025, quadrupling in size thanks to industries like automotive, medical and aerospace (Lux Research, 2013).

Why is 3D printing so popular amongst so many different industries though? Well, its enormous demand may very well come from its versatility. The technology burst through the market with a variety of processes, as well as materials, best suited for very specific, as well as broad, ends. Its previously mentioned cost-effective nature is, as well, not to be forgotten when debating its notability, as money is in the very root of capitalism.

It is estimated that 3D printing will not, in any way, replace the previous, more traditional, forms of manufacturing, but it has earned its rightful place amongst them as a production technology that is cost effective, fast, synonymous with quality and doused with a huge potential for customization (Attaran, 2017).

One of the industries that has been taking great advantage of the use of addictive manufacturing is the automotive industry. It's constant need to push technological boundaries, stemming from the fact that it is one of the most competitive industries in the world, has inevitably concluded in the need to search for new, fast and precise methods of fabrication. To fulfill that need, the automotive industry, has turned to and has been implementing the use of addictive manufacturing in its process of creation, printing customizable car parts, as well as tools. This enables, of course, the companies involved to produce lower stock levels, as components can be printed on demand (Vasco, 2021).

> The strong trend on energy consumption decrease poses new challenges regarding vehicles design, performance, and regulations compliance. AM is the key-enabling technology for new vehicles considering the actual paradigm shift from the common combustion engine to alternate motion systems. (Vasco 2021, p.505)

The industry has been using 3D printing for nostalgic purposes also, as 3D printing's customizable features allow for one to produce any part they desire. By any, I mean all, as the Australian owner of the Delage Type-S that competed at the 1914 French Grand Prix, Stuart Murdoch and engineer Grant Cowie, printed the correct parts to restore the famous car, which have not been in production for long years (Pepper, 2017).

Image 2 - Delage Type-S at the 1914 French Grand Prix, by Philip Guilfoy [2]

In de medical industry we have seen a new model of hearing aid since 2000, made possible only by implementing 3D printing technology in its arsenal. The companies Materialise and Phonak partnered up and released in that year a new method of conception that would reduce the hearing aid manufacturing process from 9 unreliable steps to one carefully curated to enhance not only speed and efficiency, but also accuracy (Sharma, 2013).

At last, the aviation industry too commanded efforts into capitalizing in the addictive manufacturing route. One such efforts marked a point of great importance in history itself. In 2018, GE Aviation printed no less than 30 thousand Colbat-chrome fuel nozzles, components of their LEAP aircraft engines. Those particular parts, previously, had to be composed of no less than 20 separate parts. But when 3D printing was implemented into the process, those singular parts were meshed into one single unity, lighter and stronger than it ever had the capability of, using those traditional methods. Besides being 25% less heavy and possessing much greater resistance the 3D printed parts also save GE Aviation 3 million dollars, or about 2.8 million euros, per aircraft (GE Addictive, 2018).

Image 3 - Colbat-chrome fuel nozzle for LEAP engine [3]

2.1 How does 3D Printing Work?

The 3D printer works about the same as a normal, ordinary inkjet printer, the difference being that instead of printing ink onto paper, 3D printers make use of material, transforming it in order to create layers that together form a three dimensional good (Berman, 2012).

To achieve the final product, a digital blueprint of the object is created making use of a CAD software. After the digital model is complete, the file is then transferred to the 3D printer who achieves the conception of the final product planting layer by layer of material, each of them being about 0,005 to 0,013 inches, or 0,127 to 0,3302 millimeters (Hiemenz, 2011).

> Most commercial 3-D printers have similar functionality. The printer uses a computer-aided design (CAD) to translate the design into a threedimensional object. The design is then sliced into several two-dimensional plans, which instruct the 3-D printer where to deposit the layers of material. (Attaran 2017, p.678)

No 3D printer was built to deliver the same results, as some of them are best suited for melting plastic filaments delivering them onto a platform through a nozzle, while others use UV lasers to melt and form photo reactive resin into the finished product and even ones which spray material on a flat plane, or laminate sheets of the designated material until the desired form is achieved. Since 2010 the ASTM group set a series of standards with the goal of differentiating and classifying the various 3D printing methods into 7 elusive categories (3dprinting) in the ASTM 52900:2015 Standard Terminology for Additive Manufacturing Technologies, which was later replaced in 2020 by the ISO/ASTM 52900 Standard Terminology for Additive Manufacturing – General Principles – Terminology (Alexander & Wake & Chepelev & Brantner & Ryan & Wang, 2021)

2.1.1 Vat Photopolymerisation

The first category, Vat Photopolymerisation, is a method which uses a vessel filled with photopolymer resin, in a liquid state, made to harden by a UV light source. Being one of the earliest forms of this production method, it is generally the one with the greatest predisposition for best surface finish as well as accuracy, with the downside of presenting finished projects who tend to pale in comparison to other AM methods when the subject of such comparisons is the durability of the product. This AM technique was divided into 3 categories, SLA, DLP and CLIP (Petrie, E.).

Stereolitography (SLA) is the Vat Photopolymerisation technology which is the most commom. Created in 1986, by the company's 3D Systems founder and 3D printer father, Charles W. Hull. This method employs, of course, the use of a UV laser to harden the resin layer upon layer, until the object is fully formed. The laser performs a cross section path, mimicking the pattern it was programed to, through the perceivable surface of the resin in its liquid form, solidifying it, as to join with the solid layer previously solidified (3dpinting). While this method can be employed for personal use, its financial cost makes it hard to classify this printer fit for that purpose (Kim & Seong & Her & Chun, 2019).

Each layer is about 0,05 to 0,15 millimeters, as so, this is the distance the elevator platform descends upon after each layer's completion. A blade filled with the photopolymer resign then runs its course upon the object in progress packing it with renewed material. This fresh layer receives the same solidifying method as the previous ones, joining them in the completion of the final project (3dprinting).

DLP, or Digital Light Processing, has been categorized as a process which has many aspects in common with SLA, being that its only defining characteristic is its distinct light source. Instead of employing heat through laser beams, this method of fabrication uses more traditional light sources, by that I mean the old trusty lamp, or arc lamp. This is viewed as one of the fastest 3D printing methods in existence (3dprinting).

The CLIP method relies upon a very specific technological process by the name of Digital Light Synthesis (3dprinting). Build with speed in mind, as the previous processes were not fast enough for any type of production other than (Petrie, E.). this process consists of the employment of a high-performance LED light engine that conveys a series of UV based imagery through the route of a cross section in order to carefully construct the resin into the desired shape. This method uses oxygen to its advantage creating a dead zone in

which, through an O^2 permeable window, it allows for a very narrow assemblage of liquid resin to lodge between the window and the already printed bits prototyping (3dprinting).

This process alone cannot constitute of a finished product which can be used as means, for that a second process must be employed that consists of cooking the 3D printed object, by means of either a thermal bath, or an oven (3dprinting).

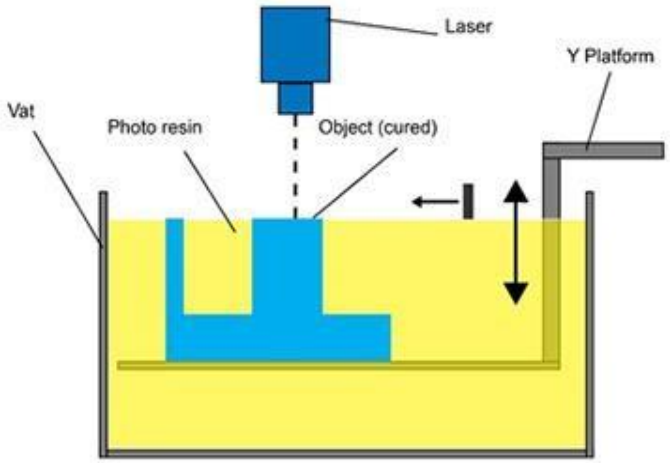


Image 4 – Vat Photopolymerisation, by Loughborough University's Addictive Manufacturing Research Group [4]

2.1.2 Material Jetting

The second major category is Material Jetting. This method works with much similarity to an ordinary inkjet printer, disposing the material, in the form of tiny drops, layer by layer through a small, thin nozzle, then solidified by the usage of UV lights (3dprinting).

When working with this particular type of printer, low viscosity materials are applied in the construction of goods, a lot of times held together with the help of wax. This technique allows for one to create a product that not only has a perfected finish, but also enables more than one color and/or material to be placed upon one single creation (Petrie, E.).

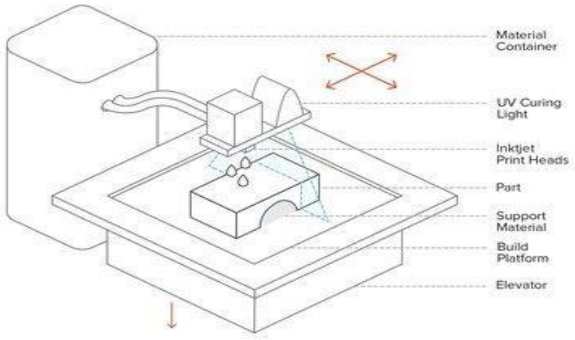


Image 5 - Material Jetting, by 3D Hubbs [5]

2.1.3 Binder Jetting

Developed by the MIT in 1993 and licensed by Z Corporation in 1995, the third categorization of the 3D printing method would be Binder Jetting, which, as its own name indicates a binder between two materials, mixed together to form one final product. Powder is spread, in equal layers, through the building chamber as a liquid form binder agent secretes by the means of jet nozzles that stick the powder chosen allowing it to take the form of the desired 3D printed object (3dprinting).

This method is often used to produce metal parts, although sand can also be used in this AM process. It also has the unique trade of not requiring heat during the creation of goods, which in turn allows for bigger parts to be printed (Greguric, 2019). This AM production method unfortunately does not come without a weakness, as the finished goods tend to present roughed up edges, giving a not so aesthetic finish to the product (Petrie, E.).

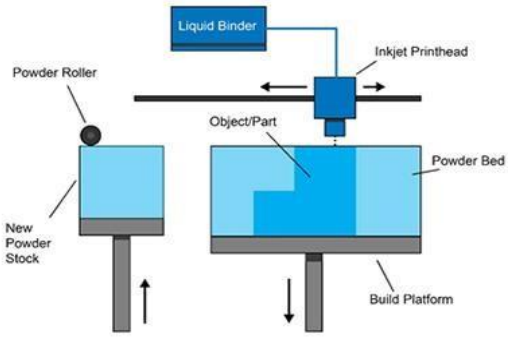


Image 6 - Binder Jetting, by Loughborough University's Addictive Manufacturing Research Group. [6]

2.1.4 Material Extrusion

Being the most commonly used 3D printing tech, the Material Extrusion was divided into 2 subcategories, FDM and FFF (3dprinting).This kind of production method although inexpensive and versatile, as different colors may be added in the process, is also slow and requires a substantial amount of energy to work, as the filaments used in production require massive quantities of heat to bent to the desired structures (Petrie, E.).

Invented by Scott Crump in the late 1980´s and trademarked by him, Fused Deposition Modeling or FDM, makes use of plastic filaments or metal wiring which are neatly folded into an intertwined coil shape. The material passes through a nozzle which controls the quantity of material the final object receives. Heat radiates from the extrusion nozzle which helps mold the chosen fibers into the desired shape as it moves either in a horizontal or vertical line via a precisely calculated mechanism, carefully guided by a Computer Aided Manufacturing software, or CAM. As every form of 3D printing, this method is constructed by layers as the product hardens upon exiting the nozzle (3dprinting).

FFF, or Fused Filament Fabrication, was a term coined by members of RepRap Project and counts with its own sub classification of filament 3D printer configuration (3dprinting).

The 3D printer Darwin, RepRap's fist ever creation, was programed with one of those same configuration methods, the Cartesian – XY – Head. This process works through the geometric movement of several points. The printer's extruder head dislocates around a calculated X to Y axis, while the bed moves along its Z axis (3dprinting).

The second configuration, Cartesian - XZ - Head comes precisely with the second RepRap creation, Mendel. Instead of its extruder head moving over the XY axis, as their previous model, this printer's head moves over its X and Z axis, while the print bed moves according to its Y axis (3dprinting).

The Delta configuration would be the fastest of all these configurations, as it, true to its name, possesses a triangular shaped extruder head. This allows the printers moving parts to be very light in weight, in turn then, resulting in its optimal speed (3dprinting).

The last of these configurations is the Core XY. Gaining a lot of popularity in the past few years, it differs from any method previously referred to as it relies on two parallel stationary motors over the X and Y axis separately and this is exactly what makes it faster than the more traditional configurations like the Cartesian – XZ – Head (3dprinting).

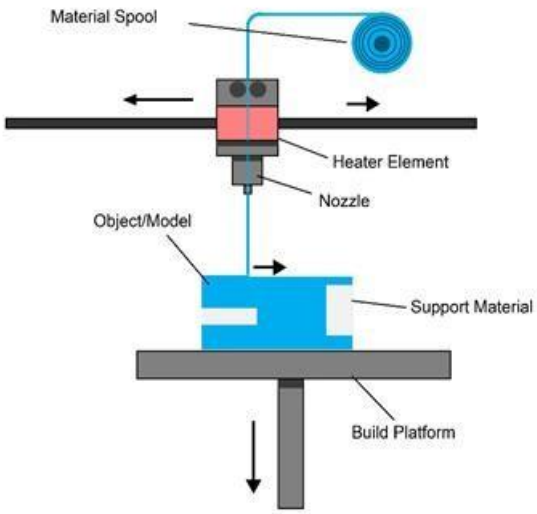


Image 7 - Material Extrusion, by Loughborough University's Addictive Manufacturing Research Group. [7]

2.1.5 Powder Bed Fusion

The fifth major 3D printing category, Powder Bed Fusion, just like the first category, is divided into 3 subcategories, MJF, SLS and DMLS, being that the SLS is the most commonly used amongst them (3dprinting). This technology is very similar to binder jetting, the difference being that, in this case, heat is applied to the product, be it via a laser or an election beam (Petrie, E.).

This is a fabrication method which, due to its own configurations, renders the need for structural support obsolete. Powder surrenders the form in creation and supports it instead and it is this characteristic that allows for this to be a production method suited for large forms that would not be possible using other AM configurations. It comes at a great cost though, as its low waste capabilities may be outshined by the high price placed upon its equipment (Petrie, E.).

Multi Jet Fusion, MJF, was dreamed and conceived by Hewlett Packard and operates by the motion of two arms. One, a sweeping harm, dumps a film of powder, so that the other arm, equipped with inkjets and a binding agent, can coat the powder material in order to achieve a smooth and precise finish to the finished product, which is then exposed to heating agents that seal each layer by capitalizing on the reaction of the two elements. This process allows, due to its binding nature, that the final product be

planed down to the voxel, a 3D pixel, granting the wearer to use different colors in the same part (3dprinting).

SLS, Selective Laser Sintering, utilizes the immense potentiality of a high-power laser to merge tiny powder particles of material, be it glass, ceramic or the common plastic. After the laser, in a cross-section motion, runs its course in the formation of a layer, the printer's bed descends by the thickness on exactly one layer so the process can repeat itself over and over again (3dprinting). SLS' flexible nature, provided by its capability to print a multitude of materials and its ability to fabricate complex structures without needing support, allows for the use of this type of printer in numerous industries. However, it's size and elevated price make it unfit for personal use (Kim & Seong & Her & Chun, 2019).

The last of the Powder Bed Fusion's subcategories, the Direct Metal Laser Sintering, or DMLS, works in ways that are very similar to the SLS process, going as far as being almost the same. The major difference being the material used, as DMLS, as the name clues to, uses metals in their fabrication process (3dprinting).

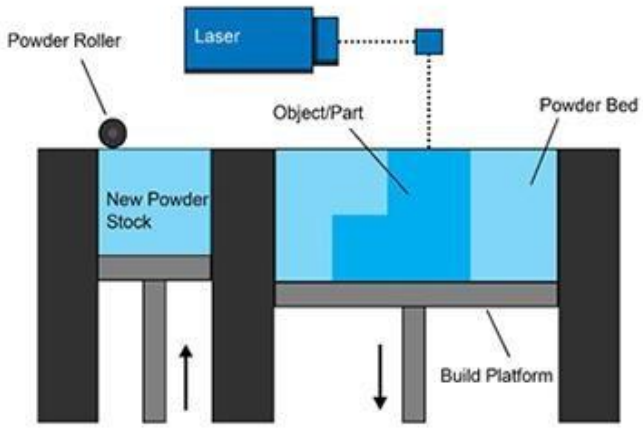


Image 8 - Powder Bed Fusion, by Loughborough University's Addictive Manufacturing Research Group. [8]

2.1.6 Sheet Lamination

The sixth ASTM category is Sheet Lamination, which, unlike its listing predecessors, uses sheets of material, be it metal, plastic or paper, locked and banded together by the use of external forces (3dprinting).

This process, due to high diversity of materials it has the capability to employ, can be very inexpensive. Besides the material versatility it displays, Sheet Lamination also allows for different materials to be bound together, as well as large parts to be printed. But, as other AM processes have displayed disadvantages, so does this one, as it is a method which shows low capability of building large structures, or even precise shapes (Petrie, E.).

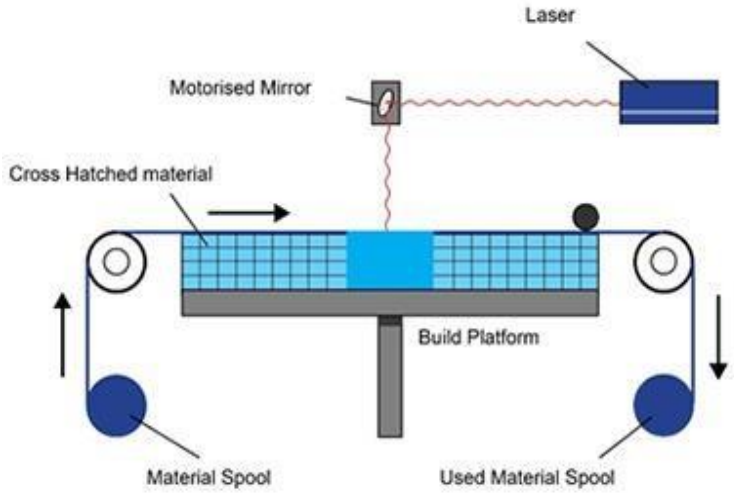


Image 9 - Sheet Lamination, by Loughborough University's Addictive Manufacturing Research Group [9]

2.1.7 Director Energy Deposition

The last of the great categories is Directed Energy Deposition. This type of technology works with metal and makes use of a robotic arm with multiple axis configurations. In that arm, a nozzle disposes of powder, or wired metal into a plane which is then melted together by a powerful energy source, like a laser, electron beam or plasma arc. This form of construction is mostly used by the high-tech metal industry or for rapid manufacturing purposes (3dprinting), repair or adding supplementary material onto an already existing product. That is why this AM type technology is considered by many as the most expensive and complex between all the previous processes (Petrie, E.).

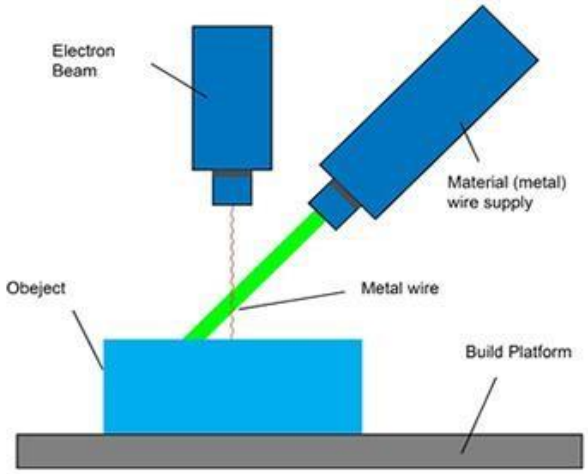


Image 10 - Directed Energy Deposition, by Loughborough University's Addictive Manufacturing Research Group. [10]

2.2 Materials

As of these days, there are 6 different types of materials, as well as forms, which can be utilized in 3D printing production. Depending on the 3D printer the materials, plastics, metals, ceramics, paper, concrete and even some edibles like chocolate, can come in the form of wired filament, powder or liquid resin. Some of these materials are best suited for certain types of printers, but it is true that polymers are the most commonly used in this sort of industrial production system (3dprinting).

As we look to the viability of implementing this king of production technique into the fashion industry, we would have to, as designers, look into understanding the kinds of materials that are available to this method, which are not very common to this particular industry that relies on the usage of textiles. It is not impossible though, as entertaining certain rather unconventional modeling angles may serve to manipulate the flexibility and comfort of the garment (Sun & Zhao, 2017).

Designers that embark in this type of method of creation have to strategize procedures way out of their comfort zone, not only understanding the material they are employing in their design, but changing their design method all together, adjusting to knew kings of knowledge, such as 3D CAD modeling techniques, post-printing care and process and, above all, types of maintenance required for these new 3D printed materials (Sun & Zhao, 2017).

Chapter 3 - 3D Printing in Fashion

Ever since the dawn of time, the human being, as an intelligent species, has been coming up with new and creative ideas to make its stay on Planet Earth as comfortable as possible. Mankind discovered fire for warmth, made weapons for hunting, discovered how to plant seed and domesticate animals in order to be able to build a place to call home. Now we're not faced with the difficulties of the past, but we've gained new hazards to face and created, as we evolved, increasingly sophisticated solutions.

Our quest as a species toward the new and pragmatic has led us to the wondrous world of technology and aligned with our need for connectivity in a world where, now more than ever, people seem so distant. Thus, the concept of the wearable evolved from simple eyeglasses to a world of possibilities (Sawant, 2022). In the middle of a global pandemic, where seeing family and feeling the warmth of a human being was, for lack of a better term, forbidden, technology has been the saving grace of the modern world and the fashion industry might have a role to play in that alliance (Cahn & Selinger 2022).

We have been turning towards streaming services for comfort, facetiming platforms such as Facebook and Discord to be able to see our loved ones and feel like we still belong in this broken world. We have been using technology to keep us grounded as we try to swim through all the thoughts that make us feel like wondering strangers even to ourselves (Allen, 2022). Although there has been some backlash towards our increasing reliance on technology, as people seem to weigh the true benefit of a more technology filled world and miss the feeling of belong that comes from looking someone in the eye, technology has been extenuative, for many people, as we navigate through the Covid 19 World Pandemic (Cahn & Selinger 2022).

All the technological advances we've had the pleasure of witnessing in the 21st century come from a long fulfillment period of one single wish: comfort and safety. As a collective species we demanded the impossible and a few brilliant minds managed to deliver it to us beautifully. The last 200 years or so were simply unbelievable in terms of technological development. We've had three industrial revolutions (Schwab, 2016), the man landed on the moon (NASA, 2023), the internet was created (Science+ History Museum, 2020) and the term wearable flowered handsomely from common eyeglasses to a world of potential and connectivity, as previously mentioned (Sawant, 2022).

But still, through all the amazing new things humanity has accomplished, the industry of fashion seems to fall behind, as the archaic methods of confection used by our

great grandmothers are still quite the same as the ones we use in this day and age. This industry has kept its creative efforts focused into lighting a burning desire into their consumer's heart, the desire to become someone else, to become some designer's perfect illusion before their peers. The problem for the fashion industry has never lied with the consumer's pursuit for perfection and the creator's ability to deliver, it is, however, beginning to lie within the blatant stagnation of the method of product development (Carlota, 2018).

The introduction of new technologies, digital technologies, such as the ones provided by the 4th Industrial Revolution, has the potential of becoming the saving grace of a lot of industries and to raise the quality of life of millions of people (Schwab, 2016), within those new technologies, 3D Printing would be the one who could undoubtedly have the most exciting role in the fashion industry.

These new technologies that allow, not only for connectivity and speed, but also for a major reach into becoming what the new consumer needs from the market. The new consumer that was born into the digital era, which comes with new found demands thrown into even the world's major brands, which now have to worry about details that hadn't fazed them, at all, previously. The new consumer worries not just about the quality of the product he's consuming. He now worries about ethics, sustainability, values and transparency (Forbes Business Council, 2021).

In our days, the social media days, young consumers have the power of unlimited information, very literally, at their fingertips and more terrifyingly, instantly. Many major brands have had to battle their way through controversies that would never have plagued them a few years ago, exactly due to this novice power. Controversies have not, as of yet, brought down a huge titan of the couture world, but the saying "every publicity is good publicity" no longer applies to the market (Evans, 2017).

The internet has connected people and their ideals and morals like never before. Everybody has an opinion and social media gave even the most common of Joes the reach to voice their values out to a virtual world, where millions are able to receive it and pass it along, with a sprinkle of their own mind thrown into the mix. Therefore, even though the destructive power of a bunch of pissed off consumers will never be enough to flat out end a brand, it certainly can tarnish their reputation enough to leave a figurative bruise in their otherwise pristine reputations and consequently, their revenue. Specially when taking into consideration that this consumer is more likely to trust their fellow consumers than large company's marketing campaigns (Evans, 2017)

To demonstrate this, we can look at everything that surrounds the most recent Balenciaga scandal. Back in November of 2022, Balenciaga released pictures for their new holiday add campaign which displayed literal children holding teddy bears dressed in paraphernalia evocative of BDSM practices (Kollmeyer, 2023). The public was appalled which, in turn, left Balenciaga with a massive scandal in their hands (Issawi, 2023).

The situation became even more dire when the public realized that in a separate Spring/Summer campaign Balenciaga had released another campaign for a handbag which featured a court document related to the United States v. Williams case, a ruling against child pornography (Issawi, 2023).

Both situations culminated in Balenciaga having to issue two apology statements on Instagram, on November 22nd, and take action to take down the controversial teddy bears from their website by November 28th (Issawi, 2023), which is kind of a pointless effort as the teddy bears were never the problem, their association with children was.

This of course hurt Balenciaga's end of the year sales that fell a staggering 7% decline in comparable fourth quarter revenue and the company's shares have dropped 8% as well as of February 15th, 2023 (Kollmeyer, 2023).

This comes to show that with all the power the new consumer has, wouldn't it be wise for brands to not discard public opinion? As of late we've been seeing how brands, arrogantly set in their old ways, pay no mind to the consumer, forgetting that they now, thanks to the internet, have the power to start digital revolutions (Forbes Business Council, 2021).

This new consumer doesn't ask for much, just a better and more honest would, demanding those same ideals from the brands they consume from. They praise individuality and, born in a world were all they have known was pollution and global warming, they worry for the future, seeking sustainability, iron clad ethics and a strong sense of morality (Forbes Business Council, 2021).

Many designers and brands are picking up on a new and exciting way of "giving the people what they want", as a result of contemplating the weight of public opinion in the digital era, and of course, for many designers, 3D Printing was considered as an opportunity to fill that demand.

3D printed is, after all and as stated before, pretty versatile, more so than previously thought possible, as it has, of course, started as a mere end to produce any kinds of prototypes that were never supposed to last. Now it is has come such a long way, it is capable of manufacturing engine pieces for airplanes.

3.1. 3D Printed Clothing

As mentioned before, it is no secret that 3D printing has been slowly taking over a lot of industries, producing more than favorable results for them in a speedy and cost-effective manner. The fashion industry, despite having a long way to go in terms of adapting 3D printing technology to the market, has been making very successful attempts at achieving just that (Sun & Zhao, 2017). In addition, implementing this kind of technology into the fashion industry, as well as other digital manufacturing technologies, may drop the time in which not only the product is created, but also the time it takes for it to reach the intended consumer (Carlota, M. 2018).

In spite of being plagued by the renewal of trending cycles lately, it is very important for the fashion industry to maintain the freshness it has accustomed its consumers to. But, with a production line that hasn't changed in years and old tired trends coming back, how can the fashion industry maintain the fantasy?

Well, 3D printing might just be the solution to both, as the production method forces the fashion designer to quit the delightfully childish notion of relying on nostalgia to sell. This is a beautifully innocent concept that allows many to relive better time, which is especially tempting as we try to navigate through a global pandemic that has, for lack of a better word, made us all prisoners of our own homes. But instead of reminiscing about a magnificent past, we should instead be looking to the future. A future in which new production methods compel the designer to come up with brand new methods of creation as the designer is confronted by a still, to this market, entirely experimental manufacturing technique (Sun & Zhao, 2017).

> DDM offers much more than an acceleration of the manufacturing process. An emphasis on "rapid" can lead to oversight of the numerous advantages delivered throughout the manufacturing process. DDM is not a simple revision of existing manufacturing methods that makes the process faster. It is a radical departure that fundamentally changes manufacturing. (Crump 2014, p.1)

Despite my believe that 3D printing might be one of the best things to ever happen to the fashion market, some aspects of this addictive manufacturing method have to be taken into some amount of consideration. One of the aspects in need of careful consideration is the way in which designers envision their product. Fashion designers are

taught to visualize their product from a two-dimensional perspective, but in order to create product in a 3D printer, the CAD programs, adequate to the job, demand for a huge adaptation in the way designers visualize their design, calling for a better understanding of the spatial properties of 3D printing product design (Sun & Zhao, 2017).

The skill sets necessary to produce by the aid of such method, for many designers who lack the proper education in the process of 3D printing, might come in the form of relying in a whole team of engineers to complete a task that would otherwise, given their knowledge of the normal method of production, be intuitively unchallenging for the designer (Sun & Zhao, 2017).But change is never easy and relying on a well put together team while one still lacks the teaching to stand on one's own is no sign of weakness on the designer's part. No man can stand alone and huge fashion moguls certainly need a lot of brains working for them. Why not turn some of those creative minds into mathematically inclined ones.

> Currently, 3DP fashion pioneers such as van Herpen (2017) have been teaming up with experts outside of the feld in creating unique wearable art that otherwise would have posed extremelynhigh barriers for a traditional fashion design team. Tese collaborators are often engineers who are experienced in specialty materials and architects holds 3D CAD expertise. (Sun, L. & Zhao, L 2017, p.5)

Besides the designing process, fashion designers would also be required to adapt into working with entirely new materials that differ, by a large margin, from the traditional materials associated with the fashion industry. Every material used in the process of 3D printing is somewhat a stranger to the traditional clothing production methods. It is not ordinary to stumble upon fabric made out of PLA or ABS. As such solutions need to be found in order to incorporate these unusual materials into s new way of creating long lasting, cost effective, sustainable and, above all, comfortable fabric (Sun & Zhao, 2017).

But, despite posing a somewhat big learning curve to traditional fashion designers, 3D printing technology is capable of a great deal of personalization and customization, to the point in which it has the capability of allowing tailored fits all while declining to compromise the technology's potential for the democratization of goods, or mass production (Sun & Zhao, 2017).

3.1.1. Iris Van Herpen

As early as 2011, the Dutch Fashion Designer Iris van Herpen debuted a skeleton dress (image 10), in partnership with Benthem Crouwel Architects, making the point that innovative high-tech, as well as architectural vision and structural awareness might just be the future of fashion design. After the dress made its way through the runway, in the Capriole Fall 2011 Collection, the Dutch designer cemented herself as one to keep a close eye on as she braved through the Haute Couture realm and through that splashed some much-needed refreshing technological methodology into an, arguably, comfortably stale market (Borelli-Berson, 2017).

The iconic piece was meant to represent freedom and the beauty to be found between being free and imperfect and it is now at the MET for everyone to see and appreciate all its glory (Borelli-Berson, 2017).

In 2013, both Stratasys and Materialise announced they would collaborate with Dutch designer Iris Van Herpen on an eleven-piece collection that would hit the catwalks at Paris Fashion Week. *VOLTAGE*, the collection, highlighted two ensembles carefully crafted through the 3D printing process. One of those ensembles consisted of a cape and a skirt drafted by the designer herself in partnership with architect, artist, designer and professor Neri Oxman, from MIT's Media Lab. Being that the skirt and the cape were both printed by Stratasys (Anonymous, 2013).

The second ensemble held a complex piece, a dress, designed with the help of Austrian architect Julia Koener and printed by the company Materialise (Anonymous, 2013).

Image 11 – Iris van Herpen's 3D Printed Skeleton Dress, by Luigi and Iango [11]


Images 12 & 13 - 3D printed cape and skirt, behind the scenes of the Iris van Herpen VOLTAGE fashion show, by Boy Kortekaas [12 & 13]

Image 14 - 3D printed dress, behind the scenes of the Iris van Herpen VOLTAGE fashion show, by Boy Kortekaas [14]

3.1.2. Anouk Wipprecht

Anouk Wipprecht is a Dutch designer that stives to align technological development in the garment industry with the connectivity of the human mind and society. The designer's whole aesthetics involve the concept of the exploration of the interactivity of the human brain, within itself and with its surroundings. She not only brings technological innovation into the fashion industry, but a new way of looking into what a piece of clothing can do for the individual (Bukovic, 2020).

Her belief that garments may constitute more than just wearable fabric led her to the creation of designs such as the Spider Dress. Combining Intel Edison with 3D printing (Starr, 2014), this piece is not only tough looking, but packs a mean punch as well. The Spider Dress, which opens its legs open into an attack position, stinging whoever is standing too close, might be a tad violent, but in today's sociopolitical climate, and with as much as 1 in 5 women and 1 in 75 men being sexually assaulted during their life time, according to the U.S.A.'s National Sexual Violence Resource Center (N Sexual Violence R Center, 2015), the dress might just be the perfect allegory to an underdog fighting back. By that I mean, although seemingly scary, the dress is mainly self-defense tool, as a person needs to be violating a reasonable right to personal space to be anywhere within range of the iconic piece and, on top of that, if you approach the wearer of the piece calmly, the dress will respond in the same manner, being that it's programmed to respond negatively only to violent behaviors (Starr, 2014).

The grotesque looking design, in a surprising turn of events, challenges what is thought of as beautiful and functional.

Image 15 – Annouk Wipprech's Spider Dress, by Lidia Ratoi [15]

Also, seemingly straight out of an alien sci-fi movie, the Synapse Dress combines intel tech with 3D printing and similarly to the Spider Dress, this garment's function, besides of course being a dress, is to protect its wearer, but contrary to the Spider Dress, the Synapse Dress is meant to do that while taking into account the wearer's mental wellbeing, instead of their physical safety (Materialise).

This dress' biosensors allow it to perform like a mood map engineered to act upon the body's electrical impulses. The dress is connected to a headpiece which monitors activity and lets you and other know if the wearer is concentrated on something and should not be disturbed, or if another person is too close for comfort to the wearer, being that, if the latter

one is the case, the dress will light up to 120 watts of brightness. The dress also contains a camera that can catalog moments when the wearer is either very tense or very relaxed (Materialise).

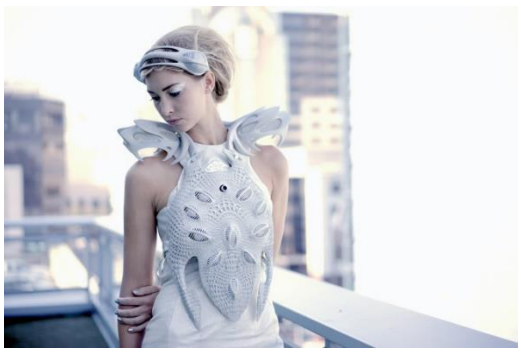


Image 16 – Annouk Wipprech's Synapse Dress, by Jason Perry and Anouk Wipprecht [16]

The Smoke Dress is a beautiful design that conveys the wearer's unsettled feelings, while looking marvelously ethereal. Similar to the self-protection feelings the Dutch designer conveyed in the last two designs, this dress involves the wearer in a delicate veil of smoke when their personal space is compromised (Anonymous, 2013). The dress, in addition to the other two, serves to create a theme and to give us a glimpse into the world Anouk Wipprecht sees and tries to warn us about. Although her designs combine futuristic aesthetics with delicate curves, it is impossible to deny that the designer has a strong need for protection, be it physical or mental and that mentality has a lot to say about the lack of safety women still face in the XXI century.

Image 17 – Anouk Wipprecht's Smoke Dress, by Anouk Wipprecht [17]

3.1.3. ZER Collection

Although the work the previous Dutch designers is outstanding in every way, it is no secret that just by looking at the intricate pieces, one cannot envision themselves using that kind of garment in their everyday life. The process of adjusting the traditional fashion design method into the technology of 3D printing is very recent, all things considered, and although full of unrealized potential, it is still a bit rough around the edges. It is this unknown factor that makes the prospect of exploring this possibility that much more exciting, therefore, entirely of significant value (Yosra, 2020).

The Spanish brand ZER Collection seized the opportunity for greatness and refused to believe 3D printing could only be used to create specific pieces, that although magnificent in their own right, might look like they belong more to the MET, to be showcased and admired, than a common person's wardrobe (Yosra, 2020).

The co-founders of the brand, Ane Castro and Núria Costa, believed that the technology had not reached its limits when it comes to fashion and they proved it when they created a relaxed streetwear collection that was constructed in its majority by 3D printing. Not only did they accomplish this, they leaned heavily into the sustainable side of the aforementioned tech (Yosra, 2020).

As early as 2017, the brand launched an urban aesthetic collection, at the Madrid Fashion Week, that featured BCN3D's 3D printing technology. The process was hard work and took about a year, but the two designers believe that the sustainability benefits of the manufacturing process far outweigh any difficulties. While making the collection, the sustainability of the 3D printing method took center stage as it allows for garments to be made using only the absolutely necessary material for the job, reducing waste to almost 0%, when usually about 30% of the materials used when creating clothing are branded as unusable (Davies, 2020).

Most of the collection was printed using TPU, as its flexibility proved to be the best fit to the collection, but, even though TPU is indeed a plastic, ZER Collection designers took the environment into consideration and used recycled materials, melted from former garments and turned into the filament that would spring the new designs (Davies, 2020).

Images 18, 19 & 20 – ZER Collection designs featuring 3D prints introduced on the Samsung Ego catwalk, during Madrid Fashion Week. [18 & 19 & 20]

3.1.4. Ganit Goldstein

Ganit Goldstein is a young Israeli designer who believes that a move from mass production to customization of design might just be the future of the market. She wants to use the potential incline towards personalization that the process of 3D printing offers, that other methods of production just aren't capable of. The designer sees the potential in melting the traditional with the modern in order for the fashion industry to evolve (Kaempfer, 2020).

In order to achieve her goal, Gordstein travelled to Japan, spending a year there to learn interweaving. There she derived inspiration from the culture, noting the beauty of Asian textile painting and traditional craft embroidery and, from there, created a kimono design which fused the traditional methods she learned in Japan with the very futuristic 3D printing technology, marrying the past and the future beautifully (Kaempfer, 2020). The kimono follows an intricate coloring method called Kasuri, the Japanese Ikat, a truly sophisticated process for it's time that consists of dying the fibers before weaving them into fabric [(2015) Kasuri]. However fascinating Kasuri is, the true piece de resistance of this garment might just be the 3D printing method used to create it (Kaempfer, 2020).

The way Goldstein found to introduce 3D printing elements into a textile skeleton in order to create the 3D printed fabric allowed for a whole new range of movement and flexibility all while keeping the fabric thick and functional (Kaempfer, 2020).

Image 21 – Ganit Goldstein's 3D printed Kimon [21]

3.2. 3D Printed Accessories

When it comes to the transition of 3D printing into the industry of fashion, the accessories are certainly a more popular venue into achieving its continued popularity. This technology's capabilities allow for it to, as of now, be more geared towards the production of accessories, more so than the various attempts at creating wearable fabrics (BCN3D, 2020).

Items like shoes, jewelry and bags are a safe gateway into introducing 3D printing into the market. Their structural needs, materials and overall nature has a predisposition towards this kind of method, as opposed to clothing, which evolves into a structural maze when the complex arrangement of traditional fabric is to be translated into any kind of 3D printing software (BCN3D, 2020).

3.2.1. NIKE

As of 2013, NIKE turned to 3D printing in order to manufacture their product. During this time the Sportswear company, after a period of experimentation, launched their first pair of 3D printed sneakers, the NIKE Vapor Laser Talon. They were football cleats, printed by Selective Laser Sintering (SLS) and weighed as little as 156g (manufactur3d, 2020).

Image 22 - NIKE Vapor Laser Talon [22]

NIKE didn't truly emerge itself into the process of 3D printing until 2016, when the brand sought to shift their focus into an in-depth exploration of the benefits of 3D printing in the designing process of footwear. What cemented 3D printing as a worthy fabrication process that year was the company's partnership with HP, in collaboration with the American athlete Allyson Felix. The Nike Zoom Superfly Flyknit were created for the sprinter to compete in the 2016 Rio Olympics (manufactur3d, 2020).

Image 23 – Allyson Felix's NIKE Zoom Superfly Flyknit, at the 2016 Rio Olympics [23]

The company's desire to partner with bona fide athletes is nothing new, do it is to be expected that as the company moves towards a new method of production, that much would stay the same. NIKE's relationship with the big names of sports and pop culture is what kept this industry giant at the top of its game for so long. For a company founded in 1964 and renamed NIKE in 1978, the sportswear brand has managed to stay relevant by bringing new faces into their projects. Along with recognizable faces, in 2017 NIKE, which had hit a stagnated sales period, decided that the future was with 3D printing and that the technology, along with a new sales and marketing policy, was the catalyst the brand needed to move forward (manufactur3d, 2020).

3.2.2. Doug Bucci

Doug Bucci is an artist, as well as an educator in the field of Jewelry. The Assistant Professor and Metals/Jewelry/CAD-CAM Program Head at Tyler School of Art and Architecture, in Philadelphia, dabbles in the world of 3D printed accessories by exploring biology. He takes inspiration from nature as he analyses cell patterns as well as the visual effects disease has in the body (Doug Bucci Official Website).

The best representation of this kind of artistry would be his Trans-Hematopoietic neckpiece in black. Composed of 3D printed nylon and dipped into idye poly, fabric dye, in order to create a hazy gradient effect to represent the various stages of life itself (Shapeways 2017).

Image 24 – Doug Bucci's Trans-Hematopoietic neckpiece in black, by Sienna Patty [24]

3.2.3. Nervous System

Nervous System is an American based 3D printed brand that designs items such as jewelry, cups, vases and lamps, as well as decorative sculptures. The brand is intensely inspired by nature, creating intricate patterns by combining scientific research, mathematics, computer graphics, biology and architecture into tangible pieces that are reminiscent of cell patterns, shapes found in sea reefs, veins and algae (Formlabs, 2018).

One of such inspirations was sea sponges, in 2018, when the brand created a ceramic 3D printed jewelry collection. Fabricated with Formlabs Ceramic Resin, it proved to be a more versatile process than traditional manufacturing processes, that is because the kind of intricate and minutious pieces the studio wanted to create could not have been possible were they to use a cast, instead of a 3D printer (Formlabs, 2018).

Nervous System started by creating a teapot and teacups set using the ceramic 3D printing resin, but they felt like that kind of big object is very large and hard to make affordable, so they decided to try to make jewelry with the material, the Porifera collection (Formlabs, 2018).

Image 25 – Nervous System's Porifera ceramic collection [25]

Image 26 – Nervous System's Porifera collection, sketches and inspirations [26]

3.2.4. Diana Law

Originally from Seattle (Barr), Diana Law is a French based fashion designer that found 3D printing to be of utmost interest, so she left her career in French Haute Couture to create something new, something that felt like the future. She has education in both fashion and jewelry design and in 2014 she founded her 3D printing jewelry business (Delgado, 2021), in which she created stunning pieces such as pendants, necklaces bracelets, headpieces and earrings, through the process of Selective Laser Sintering, using materials such as stainless steel and an assortment of plastics in order to create intricate geometric lines inspired by life itself (Alexandria, 2017).

In 2018, the designer decided to embark in an ambitious project. The goal was to combine real precious gemstones into the 3D printing fabrication process. That proved to be a challenge that would be conquered by Spring/Summer 2019 when Diana Law presented her Identité collection, which featured all kinds of accessories containing fused precious gemstones such as sapphires (3D Sourced, 2019).

Images 27 & 28 – 2019 Identité collection, earing and necklace respectively, by Diana Law [27 & 28]

Diana Law would latter expand on the usage of precious gemstones when she revealed her 2019/20 Winter Collection, LÉvolution, when she, not only, used the familiar sapphires, but also dared incorporate diamonds into outstanding designs (Intravaia, 2019).

Image 29 – 2019/20 LÉvolution collection handbag, by Diana Law [29]

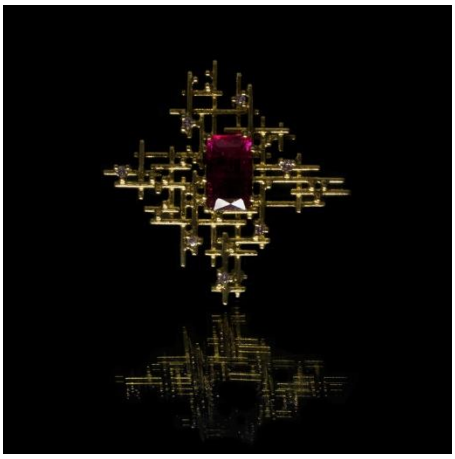
3.2.5. GUY & MAX

GUY & MAX is a jewelry brand founded by two brothers. They got into the busyness by following their father's footsteps, who was a diamond merchant. The company is based in London and has truly taken advantage of the personalization freedom's a 3D printer can bring into a brand, by making every piece of jewelry they create totally customizable. When buying from GUY & MAX, you don't just simply click on the website and buy a piece of jewelry, you embark into a detailed collaborative designing method, that completely involves the client into the creative process which includes consultations. All that so the customer may be able to create a piece of jewelry that is completely adapted to their personal taste (3D Sourced, 2019).

Besides making amazingly beautiful customized jewelry, they have implemented sustainable values into their brand as they choose to utilize only recycled metals whenever the possibility arises (3D Sourced, 2019).

Image 30 – Customized 3D printed ring, by GUY & MAX [30]

GUY & MAX tend to concentrate on custom orders nowadays, but in the past, they did make five collections that ranged from vintage inspirations, like their DECO collection that was heavily influenced by 1920's and 1930's styles, all the way to Algorithm, a collection that, as the name indicates, was, in turn, very influenced by the digital world, expressing visually a random linear computer pattern surrounded by precious gemstones (Guy & Max Official Website).

Images 31 & 32 – Algorithm Collection, by GUY & MAX [31 & 32]


Images 33 & 34 – Algorithm Collection, by GUY & MAX [33 & 34]

3.2.6. Adidas

As early as 2014, the giant that is the Adidas brand, launched the first ever shoe prototype to feature a 3D printed insole, the Futurecraft 3D. Just a year after they announced a 5-year strategy plan, the “Creating the New” in which details of the next steps for the world-renowned brand included the introduction of 3D printing technology into the Adidas assembly line (Gregurić, 2020).

At that time, Adidas wanted to be able to make extremely personalized footwear. The proposition was that the costumer would be able to walk into an Adidas store run on a treadmill for a little while and the company would be able to replicate the costumer's own exact footprint, taking the future of customization to a whole other level as the piece would entirely match the contours and pressure points of the foot, making sure that the athlete would be able to achieve maximum performance with the equipment (Materialize; Watkin, 2015).

Image 35 - Futurecraft 3D, by Adidas [35]

In 2015 Adidas created a prototype with Parley for the Oceans a pair of sneakers with a 3D printed insole made from plastic that was pulled from the oceans and inspired by the Futurecraft 3D, a concept that Adidas had disclosed the year prior. The upper part of the shoe was made from an assortment of plastics found and taken from the ocean while the 3D printed insole was made from recycled polyester and fishing nets (Vincent, 2015). This project, at this point, was made as a prototype representing the deeds we could accomplish in order to save the Earth, but by 2016 the brand announced that it would place one million pairs of the ocean plastic sneakers in the market by 2017. Due to the success of this effort to clean our oceans while allowing the brand to advance technologically, this undisputable global powerhouse embarked on a mission to fabricate five million pairs of ocean shoes by 2018 and an ambitious 11 million by 2019 (Verry, 2019).

Image 36 – Adidas' and Parley for the Oceans' 3D printed insole sneakers with recycled ocean plastic, by Adidas [36]

In 2017, Adidas announced that it would commence a partnership with Carbon, a 3D printer manufacturing company, and out of that partnership, the Futurecraft 4D was born, a line of 3D printed insole sneakers that began as a limited-edition product, but turned out that the 3D printed insoles where such a success that they were implemented into various different Adidas shoes from then on. This was major for the brand as it was the first Sportswear giant to accomplish such a development (Gregurić, 2020).

Image 37 – Futurecraft 4D, by Adidas [37]

Chapter 4 - 3D Printing and Sustainability

Fast fashion is a marvel of the modern world, it singlehandedly created trend cycles and changed the way we both view and consume modern fashion (Lin, 2022). After the industrial revolutions came the democratization of product, which was now created in bulk, this meant common folk gained tremendous buying power, something that had been previously reserved only for nobility and bourgeoise (Cooney, 2019). But this new buying freedom the capitalist movement brought us, also took an enormous toll on the figurative heath of the environment (Lin, 2022).

What started out as a movement meant to bring product to the masses ended up being used and abused to the point where over consumerism and the waste that comes with it can no longer be ignored. Fast fashion became a monster on its own and of course, like anything else in this world, comes with a plectrum of grey areas. There is no one way to solve the problem, that is because, while there are a lot of people who abuse their buying power and over consume stuff they don't need, a lot of times compelled by social media to do so out of an intrinsically human need to feel included (Lin, 2022), there is the other side of the coin that cannot be ignored. Those are the people that need the existence of fast fashion to survive, they don't have the luxury of buying something well made because it lasts longer and they certainly lack the funds to acquire something more expensive, just because it is sustainable.

The wellbeing of the planet earth is threatened every day and the fast fashion industry is one of the biggest contributors to its downfall. Trend cycles keep getting smaller and smaller and of course, people feel the need to keep up with the everchanging arbitrary rules of the fashion industry (Lin, 2022). The biggest problem stemming from this industry is not the consumer, I don't think, because no ordinary consumer has the power to change the world on their own.

One may even take the necessary steps into reducing their footprint, but not everybody has the financial means to be able to prioritize the sustainability of the product they are buying, even if they would like to, and let's be honest, as of now sustainable fashion is not exactly competing with fast fashion in terms of cost (Costa, 2021).

It is true that labor does cost money what's more, in the chain that is behind the fabrication of a product, ideally everyone should be paid fairly. But is it really up to a consumer with limited means to choose a $45 locally and sustainably made t-shit, when

there is a $5 option that allows the consumer to have the item they need in addition to still having money to feed themselves? I think the responsibility lies within the industry to find a better path. A way to maintain the chain of production cost effective, as well as ethical and humane (Costa, 2021).

Taking that into consideration, I think it wouldn't be unhinged to maybe place the responsibility onto the designers and the manufacturers. We can't expect people to do what's right when morals are up against their ego, so we might as well, as creators, make sure our product is both sustainable and cost effective. I don't believe the future of sustainability in the fashion industry lies within the old days when only a few had the privilege of a full wardrobe while others struggled greatly just to buy a new pair of shoes. I believe the future lies with finding resourceful, eco-friendly ways to deliver product (Costa, 2021).

I don't believe the solution would be to cut down on the consumerism thought, because the fashion industry is tremendously paramount to the economy, employing more than seventy-five million people worldwide and being worth more than two and a half trillion $USD (Geneva, 2021). With so many people's livelihoods depending on this market it would not be fair to strive towards the end of the fashion industry's increasing profitability, but this industry is singlehandedly responsible for a disgraceful percentage of the global greenhouse gas emissions, four to ten per cent, to be exact (Chan, 2021). All this coming from a single industry is a serious cause for concern and an obvious warning that the big names in fashion should be doing better.

4.1 Sustainability in Fashion

Although the immensity of the environmental footprint, left behind by the ever captivating alure of capitalism that plagues the fashion world, is nothing to scoff at, it is certain that a few conscious people do see the harm this industry is unloading upon our planet and are trying to rectify what years of reckless indulgence have created (Costa, 2021).

It is as certain as the sun rising in the east that we still have a long way to go, as a society, in order to save what we should have been actively preserving in the first place, but it is not a lost cause if the current shift in the consumer's mind is anything to go by. Consumers nowadays are more conscious of their consumer habits and of how they impact the community, so they demand ethics, morals and transparency from the brands they buy from, now more than ever (Forbes Business Council 2021). And although there is certainly

a need to check one's privilege when tampering with the topic of sustainability in fashion, as money and slim body types do seem to have a monopoly in the sustainable facet of the fashion industry, and ignoring that might bring more harm than good, it is unquestionable that we are witnessing considerable change already. There is a concern that has not been there before. People are talking about sustainability and a lot of people are listening and trying their best to not be active participants in the problem (Costa, 2021).

A good example of a shift in the mentality of young people is just how much people are thrifting nowadays. Something that was seen as embarrassing and a shameful reminder of one's "lower class" in the past is now seen as what it is, a way to find cool and unique items and build an eclectic and special wardrobe, that is curated to the individual instead of following set guidelines of what society deemed appropriate for the season (Chauhan, 2022). It is of course a plus that this method of assembling a wardrobe is sustainable and affordable, managing to be a good, cheep, alternative for those of us who care about the environment, but may not have the budget to splurge on sustainably made pieces (Frank, 2022).

There are two problems with this alternative though, for those who like to stay on top of modern trends, shopping vintage is absolutely not the way to go and for those of us who are on the bigger side this type of consumerism may not be the most inclusive. When the future of the planet is at stake there is certainly the need to consider better, inclusive, alternative methods of creation, because although fashion is somewhat elitist at its core and I do agree the alure of some brands is indeed liked to their intrinsic unattainability unquestionably skyrocketing the desire for the product, there must be an alternative, because there is a demand. That is why fast fashion was created, to fill the demand for affordable fashion and now, because of the dangers that market has created, we must strive to find an alternative that is affordable, inclusive and, let us not forget, sustainable (Walia, 2022).

The fashion industry is a real problem that cannot be ignored, it alone is culpable of 20% of the wasted water in the world, consuming around ninety-three billion metric tons of clean water every year, as well as roughly 8% of greenhouse gas emissions caused by human beings (Bailey & Basu & Sharma, 2022). The situation is so dire that the fashion industry consumes more energy than the aviation and the shipping sectors united (European Parliament, 2021).

Besides the obvious sustainability issues that are associated with the Fashion industry, we cannot forget the inhumane conditions that are associated with factory workers of the fast fashion brands we consume from. The convenience of buying a T-Shirt for €5,99

should not inspire us to accept the human's right violations that occur in these subpar working spaces (Chan, 2021).

Back on April 24th, 2013, there was an accident that shocked the world and brought to light the horrors fast fashion brands inflict upon their workers. That day, a Clothing factory in Bangladesh collapsed, taking with it the lives of one thousand and one hundred and thirty-four people. It is immensely sad that the lives of so many people were lost, so many loved ones left scared by the tragedy and yet these kinds of misfortunes keep happening, with no one to hold these brands accountable. Years after that incident, people are still dying due to the poor working conditions they are forced to live in, for a salary that is miles from being a livable wage (Chan, 2021).

As recently as 2020, a factory incident occurred Gujarat, India, where as much as 12 people were killed due to an explosion. Even more recently, last year, eight people were killed and twenty-nine injured in yet another incident involving a collapsed building in Cairo, Egypt and, earlier that month, twenty people perished in a fire at a factory in the same exact city (Chan, 2021).

This proves then that although there are rules set in place by the 2013 Accord on Fire and Building Safety, an accord set in place after the Rana Plaza tragedy in Bangladesh, these exact same rules aren't doing their due diligence in order to truly make sure that the working conditions of these people are in fact improving substantially. They are getting better for certain, with as much as around one hundred and twenty thousand electrical, as well as fire and building hazards, that have gotten repaired since the accord was drawn (Chan, 2021).

Then enter the COVID 19 pandemic. Fashion industry factory workers had already been set up in a precarious situation, when you add the global pandemic into the mix, you start to see the cracks in the system multiply. Once the virus, and consequently the collapse of the global economy, was added to an already broken system, the heinous working and living conditions of the workers of course got even more unacceptable (Penelope & LeBaron & Nova, 2020).

According to the 2020 survey "HUNGER IN THE APPAREL SUPPLY CHAIN", a significant amount of retail factory workers were affected during the pandemic, some being outright fired or choosing to resign. The vast majority though reported that there was a twenty one percent average decline in payment, which of course led to a lot of fear towards their own future, with a whopping seventy-seven percent, that participated on the survey, reporting that at least one member of their household had gone hungry since the Covid 19 restrictions had begun (Penelope & LeBaron & Nova, 2020).

> 75 percent of workers reported that they had borrowed money or accumulated debt in order to buy food since the beginning of the pandemic. Of these, 43 percent were working at the same factory that employed them before the pandemic, indicating that even workers who were still employed were taking on debt to cope with falling incomes. Given the well-documented risk that debts can lead to severe labor exploitation, including forced labor for low-wage workers, this is a worrying trend (Kyritsis P. & LeBaron G. & Nova S. 2020, p.2).

Even if the concept of global warming might be foreign to some conspirators out there, the loss and suffering of human life should allow for an easy grasp into the gravity of the situation we are facing. This is not some distant dystopian future where the upcoming generations will have to suffer the consequences of the strain we are putting into our home planet, this is real people, with real families, that are carrying heavy burdens and dying so we can enjoy our daily comforts Chan, 2021).

Of course, there are people in this planet that are plagued with their own hardships in life and may not be able to have access to any of the solutions that are offered in terms of sustainable and ethic buying, but that just means that the fashion brands themselves cannot afford the luxury of giving up finding new sustainable and affordable methods of production. Where the consumer has no choice in the matter, the responsibility falls onto governments and corporations to create better solutions (Costa, 2021).

Because the brands are picking up this new trend where the consumer is now looking for ethical fashion and questioning the values of fast fashion brands, there are now a few companies that are associating themselves with the fad just so they can ride the money wave and remain avoiding accountability for their actions as they have done for years, but there are, out there, brands that strive to truly deliver on their moral promise (Brown, 2022).

4.1.1. Reformation

The brand Reformation started as a second-hand vintage store located in Los Angeles, California and later began to evolve when they started producing their own sustainably made pieces and selling them as well (Reformation Official Website). Reformation was created in 2009 by Yael Aflalo, who had previously owned a traditional fashion brand. When she visited China on a work trip, her worldview collapsed as she saw,

firsthand, just how deteriorative the fashion industry truly is for the environment (Costello, 2017).

It was then the designer saw an opening in an, at the time, fairly untapped market. She wanted to create sustainably made clothes without compromising beauty and aesthetics. She stated to W Magazine that, at the time, she couldn't find many sustainable fashion brands that were coming out with designs she would actually wear (Costello, 2017).

Taking that into consideration the brand inspires itself, not only in vintage catalogs, in order to stay true to their origins, but also in women on the streets and the customers that voice out their opinions to the brand. For Aflalo, it is true that sustainability is now a primary concern, but making beautiful inspiring pieces that make women feel beautiful is of utmost priority (Costello, 2017).



Images 38, 39 & 40 – Reformation's Alene Silk Dress, Nadira Dress and Veda Bowery Leather Blazer [38 & 39 & 40]

4.1.2. Stella McCartney

Since the iconic brand started in 2001, it has always stived to maintain sustainable goals having launched without the use of any feathers, leather and fur, as they implemented themselves as a brand that was not only in favor of protecting the environment, but also the other species that cohabitate with us on Earth. The brand took things further in 2008, when they started using organic cotton and in 2010 when they went completely cruelty free. Their

efforts didn't stop there as since then they have kept pushing to become more and more sustainable (Stella McCartney Official Website).

On September 26th, 2020, Stella McCartney published a manifesto called the Stella McCartney Eco Impact Report for 2018–19. In there the designer revealed that the brand is still very much committed to revolutionizing the fashion industry, that they had made exponential process in the years since the company has been launched and they will continue to "fight the good fight", as they still have a long road ahead of them (Mower, 2020).

Stella has revealed that her collection is 100% made from organic denim and jersey and that their 2019 summer collection swimsuits were made with Econyl (Mower, 2020), which is a new type of fabric created from ocean and landfill residue and fabric surplus from clothing companies. This new fabric was created by Aquafil in 2011 and closely resembles nylons (De Marco, 2021). The use of this material in her swimsuit collection is estimated to have put a stop to the use of 10 tons of new nylon from being used in the fashion industry (Mower, 2020). The global production of nylon was at 8.9 million tons in the year 2020 and it is predicted to rise even more in the upcoming years (businesswire), so it is safe to say that although 10 tons may seem trivial when compared to 8.9 million, change is being pushed and small steps are enough to make a change in the long run. McCartney proved that a reduction is possible, so if everybody adheres to this process, the whole world could change for the better.

Image 41 – Stella McCartney's 2019 summer collection Econyl jumpsuit [41]

4.1.3. Zara

Part of one of the largest fashion conglomerates in the world, Inditex, and created in 1975 by Amancio Ortega, the Zara brand needs not much introduction (business of fashion).

It is very well known that Zara is a fast fashion brand, therefore it might be a tad confusing to come across this title in a section of a paper about sustainability, but the thing is that a lot of people cannot afford the prices that brands like Reformation or Stella McCartney practice. In a perfect world people should not be forced to choose between ethical consuming and being able to buy a shirt and still eat and feed a family. It is because of that same sentiment that researching about the fairly new Join Life clothing in the Zara stores might be important.

The tag Join Life was created in 2020 as a result of various sustainability strategies that the brand decided to go through with. The brand estimated that they could turn 25% of their whole collection into Join Life products, but as of 2021 the tag had spread to 35% of the collection, surpassing the brand's previous goal (Swallow, 2021).

Because of previous alleged scandals surrounding the company it is imperative that we are mindful of what the company claims and ascertain for ourselves if the brand is truly trying to go green, or if it's just plain old greenwashing (Greggs, 2021), that is when a company spends more revenue into making people believe they are sustainable than they care about truly caring for the environment, according to the Dictionary of Cambridge (dictionary of Cambridge).

They seem to be trying, Zara has been taking more into consideration the safety and well being of their factory workers, they have a set of rules and allow for termination of contracts when working conditions are subpar, but when compared to other sustainable brands they still have a long way to go (Marvin, 2022). That might be due to the fact that the Join Life parcel of the brand is priced consistently with the other Zara clothing pieces, so with the goal of keeping the price small, somebody had to suffer along the way.

Playing devil's advocate, I don't believe they had another choice at the moment as research suggests that around 52% of USA and UK consumers ask from the companies that they meet both sustainability and worker human rights goals, but only a small portion of those people were actually willing to pay the price (Radia, 2019).

It is safe to say that although the brand is controversial and they are far from perfect, there is an attempt of becoming more sustainable and be it for just for publicity or true hunger to change and become a better brand, they are truly making concrete steps into

becoming more carbon neutral. These new Join Life pieces are made with at least 50% sustainable materials and they plan to keep reaching new and improved sustainable goals in the future (Greggs, 2021).

It is certainly a good thing that although Zara is not a leading lady when it comes to ethic consuming they are trying to cater to the people who want to consume sustainable goods, but are incapable of affording them and the people who find it difficult to encounter their size in second hand stores, but care for the environment.


Images 42 & 43 – Zara's Join Life Leggings Mini Flare and Mini Cut Out Dress [42 & 43]

4.1.4. ISTO

A lot of brans are very secretive when it comes to their process, its costs and of course the consequences of production in terms of environmental protection. But ISTO, a Portuguese brand, created in 2016 by Vasco Mendonça, Pedro Palha, and Pedro Gaspar, (Osorio, 2021) aims for transparency (ISTO Official Website).

ISTO is a brand that tries to distance itself from the franticness of the fashion industry. It does not care for trends or fads, finding importance in producing quality pieces that can be worn by everyday people. The brand does not have a striking collection, certainly not what I would call avant-garde or extremely creative, but they don't have to be. They offer a sustainable option, allowing the consumer to fill their need for the common wardrobe

everyday essentials that, let's be honest, everyone needs. ISTO concentrates on quality clothing stapples, that are always available on their website, rather than in creating seasonal collections (ISTO Official Website).

Besides their avoidance of the multiple collections a year system and their transparency regarding the costs of labor, they are also very sustainably conscious, as all of their suppliers have Global Organic Textile Standard certifications (ISTO Official Website).

They have a section on their official website that is precisely geared towards explaining the cost of every step of their production until the clothing piece is placed in a store and bought by the consumer (ISTO Official Website).

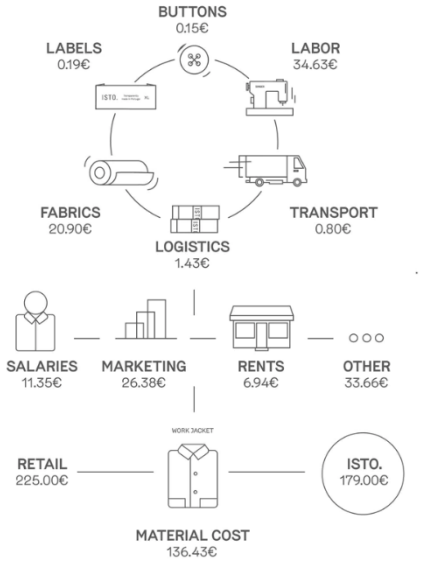


Image 44 – ISTO's production cycle and costs [44]

Images 45 – ISTO's Cotton Sweater and Women's Heavyweight Tee [45]

4.1.5. +351

+351 is another Portuguese sustainable brand, created by Ana Penha e Costa in 2015, inspired by the Atlantic Ocean and the city of Lisbon. The brand is very casual and geared towards a more relaxed Portuguese beach aesthetic. The love of the ocean is very apparent in every piece of clothing and although the pieces are casual and seemingly comfortable, they have a certain personality and attitude about them (+351 Official Website).

This brand's products are all made in Portugal, most of them with 100% organic cotton, the rest are a swimwear line they created by upcycling some unused stock from the earlier days of the +351 brand (+351 Official Website).

Images 46 & 47 – +351's T-Shirt Stripes Mulberry & Lime Yellow and Swimsuit Tie Dye Navy Blue [46 & 47]

4.1.6. Lemon Jelly

This is another Portuguese company that needs no introduction. The idea behind Lemon Jelly is around 20 years old, but the brand itself was created back in 2013, by José Azevedo Pinto (green purpose). Besides having an amazing, fresh sent of lemon, the brand prides itself in their sustainable values, as they are a vegan footwear brand that is as of 2019, believe it or not, certified by PETA, a non-governmental organization dedicated to upholding animal rights, (Lemon Jelly Official Website).

Besides having no animal products in their constitution, the fabrication process is in Portugal, using renewable energy, which lowers the CO_2 emissions by nearly 90%, all that, of course, coupled with the shoes are 100% recyclable (Lemon Jelly Official Website).

In the Lemon Jelly website, they encourage people to return shoes they believe they will no longer wear so that the Portuguese company may then breathe new life into them and transform them into something different. Besides getting the feeling of doing a good deed just by returning some old shoes they don't wear anymore, people even receive a 10% discount voucher for their next purchase with Lemon Jelly as an extra encouragement into doing the right thing (Lemon Jelly Official Website).

Images 48, 49 & 50 – Lemon Jelly's winter boots [48 & 49 & 50]

4.1.7. Unreal Fields

Unreal fields is another Portuguese shoe brand that stives for innovation, but does not want to sacrifice transparency and ethic work conditions in order to do so. All of their products are locally and handmade by family-owned Portuguese manufacturers that have

been around for generations. They do this not only to be able to ensure good working conditions and highlighting Portuguese talents, but also as a means to reduce their carbon footprint, by decreasing the need for shipping (Unreal Fields Official Website).

The women led brand was founded in 2019 and has a mission of producing aesthetically pleasing shoes, true, but its core values are in the sustainability concept. Besides the brands insistence in using local production sites, they are also committed to reducing waste by launching all of their collections with a pre order option, in order to be able to account roughly for the number they would have to produce in order to fill the demand and to cut back on waste. They also partnered with suppliers that guarantee quality sustainable organic (Unreal Fields Official Website).

Image 51 – Unreal Fiels's shoes being manufactured [51]

4.1.8. NIKE

Just like Zara, the brand NIKE is taking a few steps into the world of sustainability, but they still have a long way to go. It is no secret to anyone living after 1991, when poor working conditions at NIKE were highlighted in a published report by the activist Jeff Ballinger, that NIKE controversially employed the use of sweatshops for years in their production line. Only after these horrid conditions were highlighted, as well as protested against, did the brand actually do anything to change their behavior (Robertson, 2022).

The sportswear brand has since then implemented many efforts into becoming more conscious about their employees working conditions implementing new standards and

raising the minimum age of their factory workers. They made such strides that the Business of Fashion posted an article where they reported that the brand had truly made an impact and honestly became an example to follow when it comes to sustainability (Robertson, 2022).

NIKE has certainly made a few missteps on the road to redemption. The brand is becoming very aware of its unfortunate place in contributing, in large part, to the environmental fears and prospects that the new generations face and as of 2016 they announced that as much as 71% of the materials they use to make new products come from their own waste. In an effort into becoming more sustainable as they take a step into the future of design, NIKE, the beloved multimillion sports brand has decided to shift its resources into a noble attempt to clean our oceans (Kaufman, 2016). But after all of that effort one of such missteps happened, as recently as 2017, after they had announced all those big plans towards the brand's sustainability efforts, they somehow decided to take a step backwards and, according to the International Labor Rights Forum, decided to abandon the responsibility they had agreed to uphold towards the WRC, the Worker Rights Consortium (Robertson, 2022).

They seem to be bouncing back again, as they scored decently in terms of transparency of the brand in 2021, according to the Fashion Transparency Index, as they had also done in 2020. This maybe indicates that the brand is finally on the right path, but only time will tell (Robertson, 2022).

As of now it is safe to assume that the brand is certainly far from perfect when it comes to both worker's rights as well as environmental pollution, but greenwashing or not they seem to be trying to make an impact.

Images 52 & 53 – Nike Air Force 1 Crater Flyknit Next Nature and Nike Cosmic Unity 2 [52 & 53]

4.1 Sustainability in 3D Printing

The 3D printing process method is, at face value, considered a sustainable method of production and it certainly ticks many boxes, so it is not farfetched for people to think so (Taylor-Smith, 2021).

First of all, the production method itself seems to be a key component to the sustainability Addictive Manufacturing benefits from, for many reasons. The first one being that the fabrication process itself is thought to be more sustainable due to the lack of need for shipping. The designer can create the product's design and then send the file anywhere in the world for it to be printed, besides reducing drastically the need for fossil fuels, this and the fact that the process isn't stuck to the necessity of using molds in production, reduce the need for the use of overproduction, because the manufacturing of goods doesn't need to be in bulk as with traditional methods, the product can very well be made to order and customized and the costs would still be very low when compared to other techniques (Fleming & Kocsis, 2020).

All of this is good for the businesses themselves and not just for the environment, the storage needed for this method is entirely digital, eliminating the need for physical warehouses, the companies are able to do away with shipping cost almost completely and it is certainly not bad for the company's image if a product is able to ship faster and offer a great power of personalization and customization at a particularly low cost (Fleming & Kocsis, 2020).

Although these are very positive benefits provided by Addictive Manufacturing, we can't ignore that the electrical energy used in the production method still has an environmental impact. In those terms it seems that the variants used in the equation seem to have an enormous role, as a study made by UC Berkley suggests that 3D printers, depending on type, may be worse for the environment when compared to certain traditional production methods, when considering mass production, while other types tend to fair better in comparison (McAlister & Wood, 2014).

> (…) a UC Berkley study found that 3D inkjet printers had significantly worse ecological lifecycle impacts than traditional CNC machining for the high-production scenario they investigated, but that an FDM-style 3D printer had significantly lower impacts than CNC, and that injection molding outperformed all the other options in terms of environmental impacts. (McAlister & Wood 2014 p. 215)

The use of the raw materials is one more thing we can take into consideration when we are studying the effects of 3D printing on the environment. Traditional manufacturing methods, because they are subtractive rather than addictive, require the use of far larger quantities of raw materials, that in turn cause sizeable amounts of waste. Addictive manufacturing, as the name itself suggests, is an addictive process. The printer adds the materials methodically layer by layer, instead of stripping it down to the desired shape. This process of course lends to a more forgiving amount of waste and even when there is waste, a lot of the materials used in the process are recyclable, this is turn means that when a product comes out faulty, it is often times, due to recyclable material, fairly easy to remake the product, without trashing the material (Taylor-Smith, 2021).

Energy use must be taken into consideration as well. Although there hasn't been an absolute certainty consensus by researchers over just how much, they all agree that 3D printers consume copious amounts of energy (Flynt, (2017). We have to take this into consideration because many countries still use fossil fuels when generating energy (Nichols, 2017), so with that being the case, although addictive manufacturing has the potential to be a sustainable production method, global governments will play a huge part in the equation.

3D printing may be wasteful in terms of energy consumed, but it may as well still be considered a sustainable production method due to its ability to fit into circular economy. The traditional production method we have been accustomed to start by taking a raw material, transforming it into a sellable product and inserting it into the market where a final consumer can purchase it, use it and ultimately discard it. Circular economy sees to it that the process is not that linear and that instead of searching raw material in nature in order to produce a product, we use material from an already existing product at the end of its cycle, creating new from old and thus creating the cycle (Patwaa, & Sivarajah, & Seetharamanc, & Sarkard, & Maitid, & Hingoranid, 2019)

When considering the affordability of sustainable fashion, some issues were raised. Not everybody can afford to purchase sustainable clothing. Of course, the brands I listed previously do wonders into dismantling the capitalism-imposed system of over consumption we all are perpetrating, but they are in their majority, a tad expensive for the masses (Costa, 2021). Addictive manufacturing can help here, as lower production costs, lower storage costs and lower shipping costs would culminate in a cheaper product without having to morally compromise, as the worker wage could stay fair if the cost was taken out of other aspects of the cycle of the product (Fleming & Kocsis, 2020).

It is also no secret that the plus size ladies and gentlemen have been somewhat forgotten in the fashion world and it seems like sustainable fashion, for all their push for a

perceived moral high ground, still seem to leave those people behind. Plus size people also don't have the luxury of shopping second hand most of the time, as bigger sizes are very hard to find in those conditions. Because of this, it is inherently discriminatory to assume that the cut in production would be the best way to move forward. Everybody deserves to partake in the beauty of fashion (Walia, 2022). Some of the brands I discussed earlier, Like Lemon Jelly, had already presented a possible solution for this. As in the fix to the problem might not be found withing the reduction of production but in the economic method and there is where circular economy comes in as a better alternative (Lemon Jelly Official Website).

Circular economy is also tremendously important when we look at the state of our oceans. Microplastics and the harm they do to both humans and marine life on this planet, have been studied for a while now. It is not yet clear if the microplastics we ingest are harmful to us, according to an environmental scientist at Wageningen University in the Netherlands, Albert Koelmans, we might ingest up to more than a hundred thousand pieces of microplastics each day, so if it turns out to be prejudicial to our health, we are in for generations of victims. Although nothing is conclusive, researchers have speculated and came up with theories about the effects of micro and nanoplastics (XiaoZhi, 2021).

The other problem we face with microplastics is that, like all plastic, it takes hundreds of years to decompose and while it disintegrates, it is wondering about the planet and we have still no idea of the negative effects it might have on our health.

Microplastics can be separated into two different categories. The first category, or the primary microplastics derive from the production of products such as cosmetics and, more important for the subject at hand microfibers derived from textiles. The second type of microplastic derives from larger common use items, meant for single use, such as plastic water bottles and the dreaded plastic straws (National Geographic).

3D printing can help to curve some of the speculated side effects of this level of pollution by preventing the disposability of single use plastics. Addictive manufacturing is a production method that lends itself toward recycling thus being able to prevent those items from reaching presumably harmful levels (Kauppila, 2021). This hypothesis was to be my experiment when I started to write this paper, but due to lack of equipment I was not able to try out this kind of method. There are several videos and websites that explain how to transform these types of plastics into 3D printing filament and although I could not see for myself how easy or doable these tutorials are, I will still leave a few resources listed in the references for those who are curious.

Most of the addictive manufacturing projects out there made from recycled plastics are more of a demonstration of the possibilities than an actual new method of mass production, but with every successful project being made, comes further knowledge of the potential this kind of method is continuously showing (Kauppila, 2021).

One example of this is The New Raw. Born in the Netherlands, this initiative allowed for the creation of several furniture pieces made from recycled plastic, through the 3D printing method. One such piece would be their Second Nature chairs, made from recycled fishnets, which are one of the biggest sea pollution problems nowadays (Kauppila, 2021).

Image 54 – The New Raw's Second Nature chair [54]

Other good example of this takes place in arguably the biggest sporting event in the world, the Olympic Games, in this case the 2020 Olympic Games, which featured 3D printed podiums made from recycled plastics collected in the two years leading up to the event, from Japanese citizens (Kauppila, 2021).

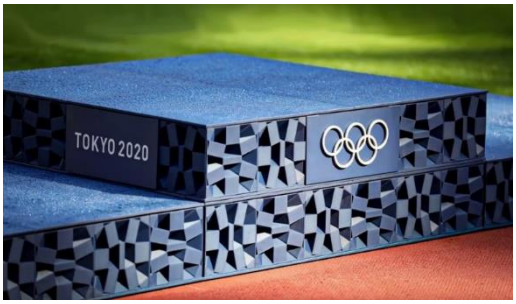


Image 55 – 2020's Olympic Podium [55]

Air pollution has a detrimental impact to life on planet earth. Air is our primary source of life, we would not have evolved to the species we are today if the oxygen levels of our home planet weren't exactly the right fit for promoting our type of life on this planet (Lindahl, 2008) and, although human beings are in nature considered to be quite adaptable, we may just be consuming our way into an early grave. There are a few factors from day-to-day life that contribute towards air pollution and factories are a big part of that (National Geographic).

Addictive Manufacturing has the potential to help with that as the method on production of 3D printing can eliminate permanently the need for factories to release harmful fumes into the atmosphere, thus doing away with two of the biggest air pollution sources related to industry, industrial and shipping generated gases.

Chapter 5 – Experimental Methodology

This chapter pertains to the practical methodology of this project.

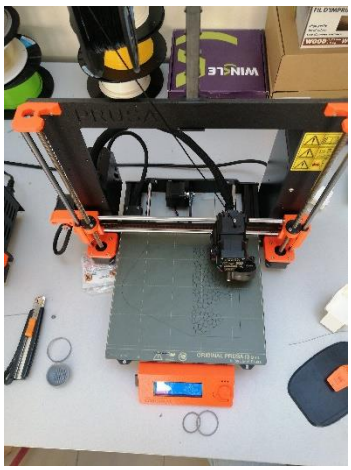
In a dissertation about exploring the possibility of not only bringing 3D printing and the 4.0 Industry into the forefront of the fashion market, but also investigating the validity behind the sustainability claims that have been raised about 3D printing, it is only fitting that a series of demonstrative tests were to be conducted during the creation of this dissertation.

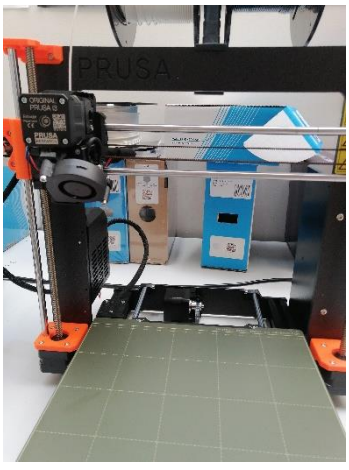
In this experimental phase, the aim was to ascertain if the cost of delivery, both monetary and environmental, was indeed something we could begin to talk about, if the possibility of printing something from one's own home is introduced into the equation it would certainly be a big win for the environment as it would negate the need for shipping. Which, as discussed before, would have sustainable benefits.

Not only that, but if 3D printing were to be a serious contender as a method of fabrication in the fashion industry, recycling and the reduction of material waste during the production of a piece would be major perks to take into consideration.

Taking that into account, as 3D printing is still largely regarded by some as a means to rapid prototyping, the possibility of really considering 3D printing a viable production method at this point had to be explored.

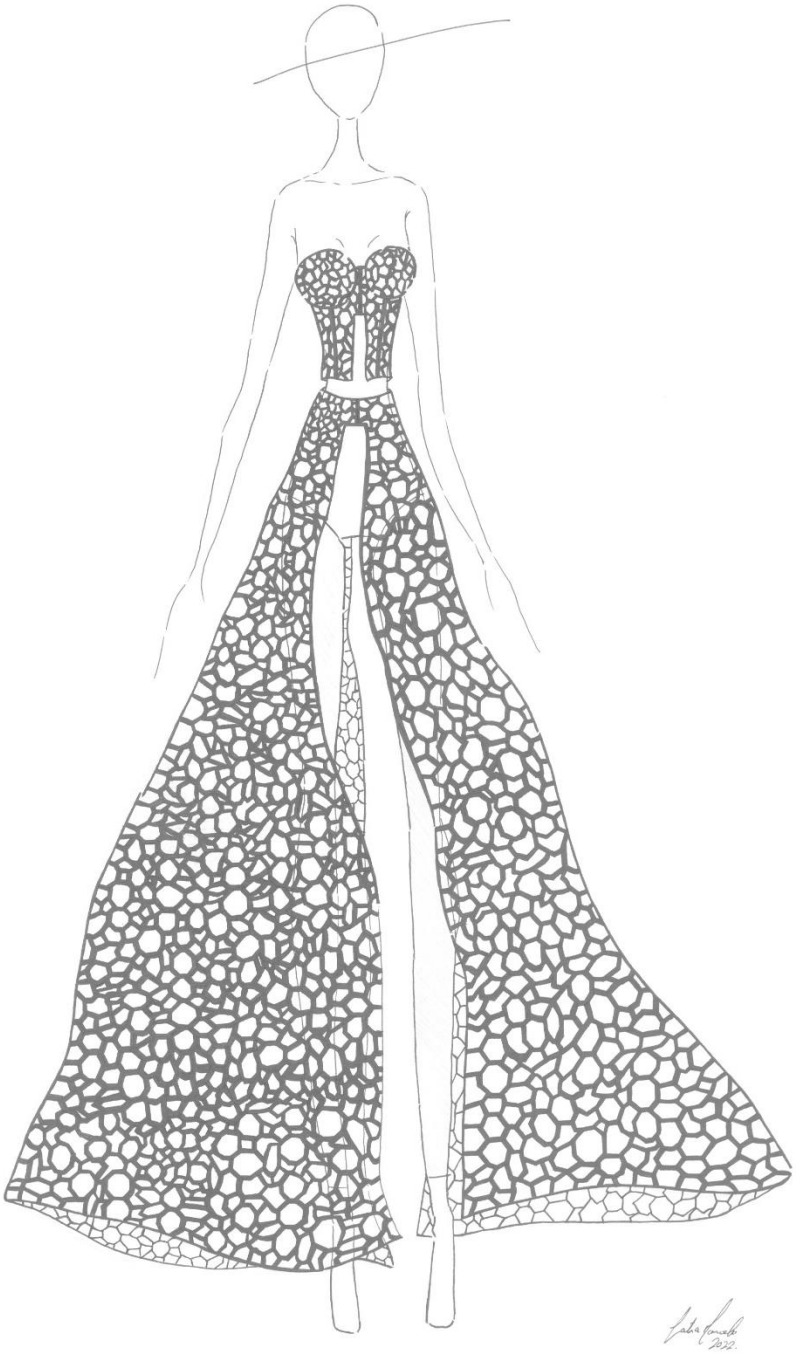
In order to do that a Pruza printer, that would be about the price range and size that a normal consumer would have in their home, was used in order to prove, or disprove, the possibility of printing clothing at home, with the technology the common person would have readily available.





Images 55 and 56– Pruza printer used in the experimental methodology

5.1. The Illustration

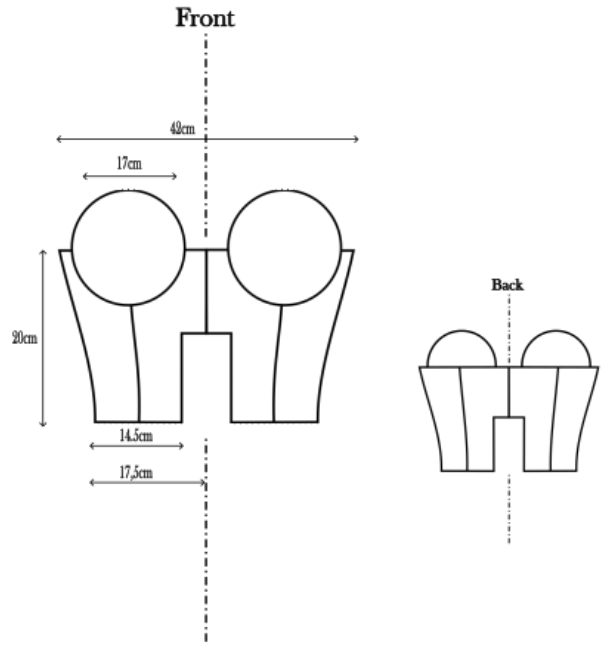


5.2. The Technical Sheets

3D Prited Corset

3D printing and its possible role in the sustainability of the fashion market

Reference: CORSET_CMDC001 Model: Corset	Size: M Colection: Spring/Summer 2023	Description: this piece is a draft of a 3D printed corset, used as a guideline to shape the tests conducted in the experiemental methodology chapter of this dissertation

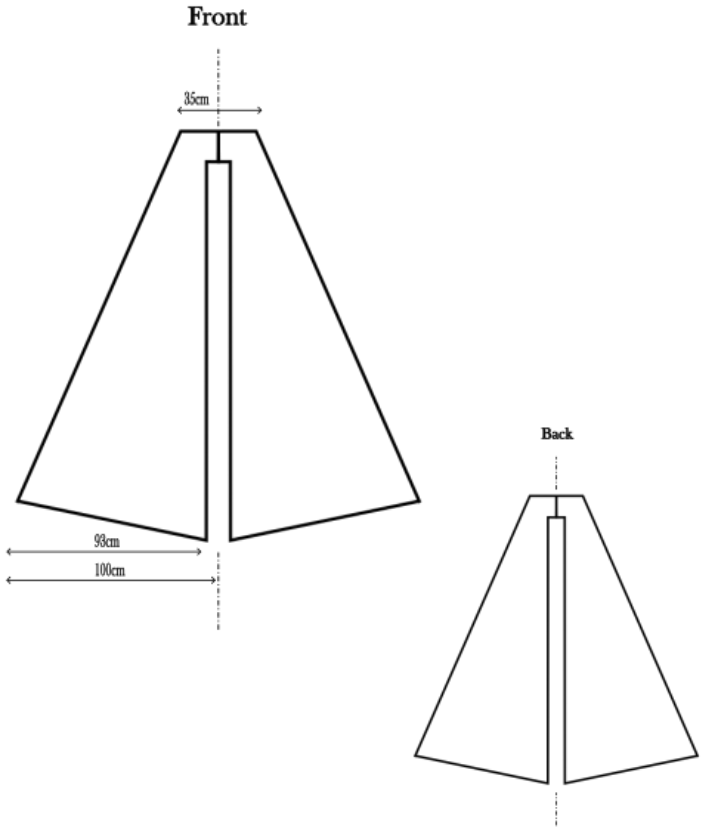


Size M measurements: Bust: 84cm Waist: 70cm Lateral height: 20cm	Color:	Material: TPU 1,75mm Brand: SUNLU

3D Prited Corset

3D printing and its possible role in the sustainability of the fashion market

Reference: SKIRT_CMDC001 Model: Skirt	Size: M Colection: Spring/Summer 2023	Description: this piece is a draft of a 3D printed skirt, used as a guideline to shape the tests conducted in the experiemental methodology chapter of this dissertation



Size M measurements: Waist: 70cm Hip: 94 cm Thigh: 52cm	Color:	Material: TPU 1,75mm Brand: SUNLU

5.3. The materials and their respective properties

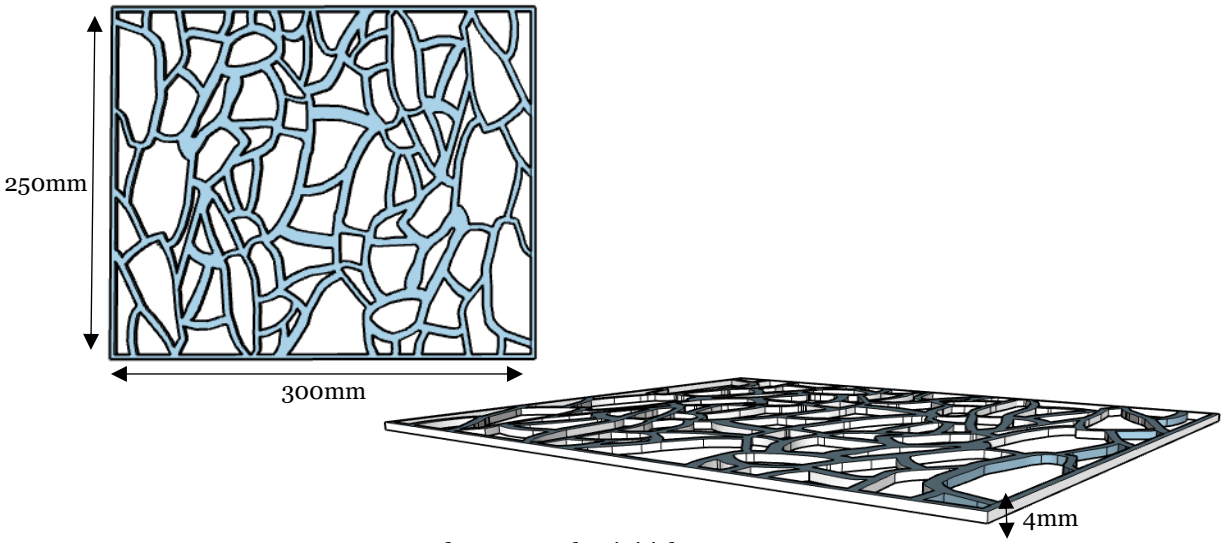
When practical experimentation was conducted, TPU was the preferred material for the job. The material has rubber properties which make it extremely flexible and pliable, making it a natural fit to the end I wished to achieve. Although most TPU's are not biodegradable, there are companies that are developing biodegradable TPU's which decompose in about 4 to 6 years and even if the material is not particularly environmentally friendly in that regard, all TPU filaments are 100% recyclable (BallisticBit).

The material used for these tests was not, in any way, ideal for what we should strive to achieve in terms of sustainability, but because it was, at the time, the only 3D printable material that had the necessary properties to conduct the tests, it was the one who was chosen for the job.

5.4. Practical Application - Testing

5.4.1. The first test: first impressions

Before the Prusa 3D printer was ever put to work, the design of the test piece was developed in the cad program SketchUp with a rudimentary design as well as roughly estimated dimensions.



Images 57 and 58 – Sample 1 initial measurements

The first test was conducted in order to access a lot of aspects I would need to consider moving forward. It helped determine the behavioral aspects of the material and the proper dimensions I needed to consider in order to achieve the desired effect.

When imputing the Sketchup STL file into the Prusa printer software, the Prusa Slicer, it was quickly revealed that my Sketchup sample had size issues, that were fixed within the Prusa Slicer program, making the sample 190x153mm instead of 300x250mm, because the former measurements do not fit the printer in use.

As per the instructions provided in the shipping box the filament came in the extruder was set to 210ºC and the bed to 50ºC, an inconsequential temperature level, since the box provided instructions dictated that the bed did, in fact, not need to be warmed up, nevertheless a bit of warmth in the bed was deemed to be the most cautious course of action.

After the sample was complete, about 6 hours later, it appeared too thick and that particular aspect made it so the sample did not hold the flexibility intended. Because of the material used, the sample had its fair share of pliability, but it was deemed it not sufficient as to construct a comfortable garment.

Image 59 – Sample 1

5.4.2. The second test: thickness adjustments

Because in the first test it was determined that the sample was in point of fact too thick for the flexibility of the material to shine through, the second test was conducted in order to test four different measurements of thickness all significantly smaller that the initial 4mm.

Appropriating the CAD design of the first sample test, 4 smaller rectangular samples were laid out onto the digital representation of the 3D printer's bed in the Prusa Slicer, all

of them with varying thickness levels. The smallest sample at 0.25mm, the second smallest at 0.50mm, the nest at 0.75mm and the largest at 1mm.

While conducting this test the printer kept jamming, seizing up every time the printing process was started. The printer eventually started the creation process of the four samples, but as it concluded the printing job, it became plainly obvious that it did not have the capability to print objects so small in thickness. Only two samples survived this experiment, samples 2 and 3, but I'd say it was a success nevertheless, as it allowed a confirmation upon the conclusion that for this material to be used in a garment, it has indeed to be made thin.

Image 60 – Samples 2 and 3

5.4.3. The third test: patten choice

For the third test, seeing as the thickness problem had been solved previously, the goal was to branch out into new patterns for the lace, as well as experimenting with a new method of pattens execution.

The 3D printing software is compatible with images composed of vectors, EPS files, so it is compatible with programs such as illustrator, not just 3D printing CAD programs as I initially thought. So, for this test, vectorized images of biometric Voronoi 2D patterns were searched and inserted into the 3D printing program Rhinoceros 5.0, creating four new pattern samples.

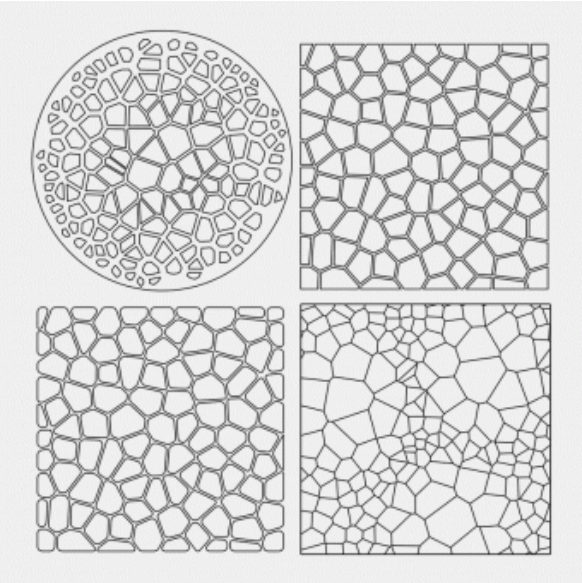
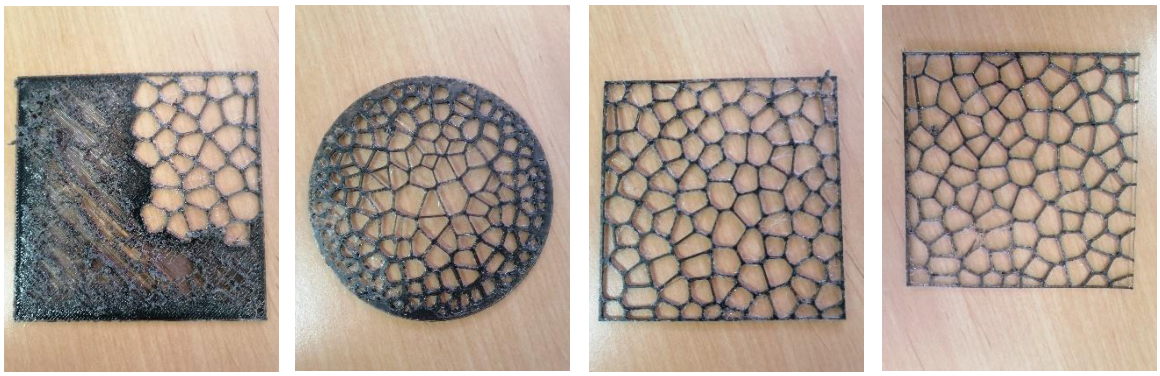


Image 61 – Biometric Voronoi 2D patterns, from Craftsmanspace

These four patterns were adjusted to fit into the correct settings in order to be 3D printed, that way it would be possible to gauge how the method and the material would behave, in terms of strength and flexibility, when confronted with certain variations in pattern.

Besides sample 4, all of them came out reasonably and allowed for a clearer understanding of what was intended for the final product. Sample number 4 had an error, but as it came out to be an interesting aesthetic, maybe the printer's mistake would not be in vain. I consulted with Professor Gouveia and we both agreed that it was worth it to try and replicate the same mistake intentionally.



Images 62, 63, 64 and 65 – Biometric Voronoi 3D patterns, samples 4, 5, 6 and 7

5.4.4. The fourth test: volume

In the fourth round of testing, volume was added into the mix, as I tried to gage what kind of behaviors the material would have when volume structures were added and of course if the, relatively inexpensive, Pruza 3D printer we were using was capable of handling the addiction of volume into the mix.

I also talked to Professor Guerreiro about the error from the last test that we were aiming to try to replicate, but Professor Guerreiro assured me that it was nearly impossible to attempt that pattern and texture by design. But still we left a completely filled square in hopes the flaw would repeat itself, so the sample 9 was printed alongside the others.

In order to print volume into the piece, the Rhinoceros tool was used to design the four pieces and then the file was transfared to the PruzaSlicer.

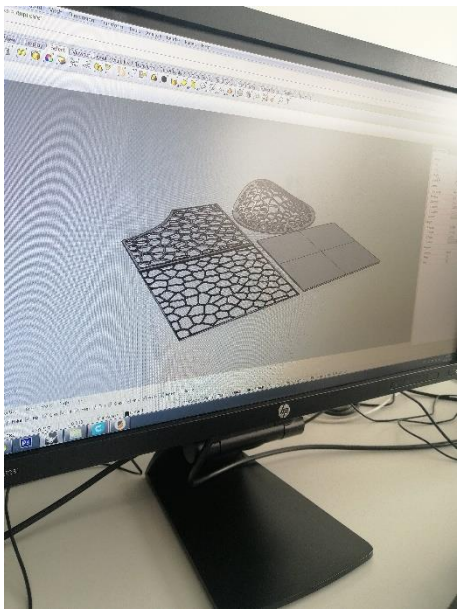


Image 66 – Designing the pieces on the Rhinoceros tool

This test failed and volume was not achieved. The printed had an error again and there was something wrong with the structure of the piece with volume. Nevertheless, I didn't consider the test a total failure as the grid pattern that was left behind on piece 8 was certainly captivating, it was smooth in texture and aesthetically appealing. So, for the next test I would try to replicate it.

Images 67, 68, 69 and 70 – Biometric Voronoi 3D patterns, samples 8, 9, 10 and 11

5.4.5. The fifth test: recreation of sample 8

As mentioned before, the fourth test failed, so Professor Guerreiro suggested that we try to analyse and prepare the print through the Rhinoceros software, because, up until now, we had been using only the PruzaSlicer software that resulted in some issues.

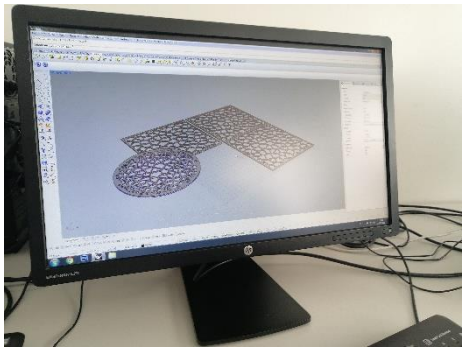
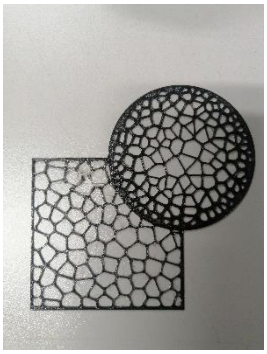
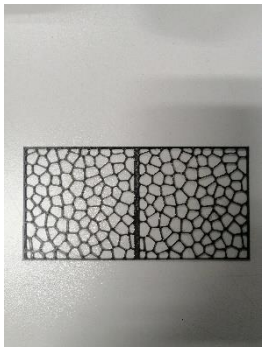
With this process of analysing and tuning some parameters in Rhinoceros software, we met the end goal and we were able to recreate piece 8 , resulting in a much detailed print.

Images 71, 72, 73 and 74 – Biometric Voronoi 3D patterns, sample 12

5.4.6. The sixth test: seams

In his next step, we tried to test how we could connect different pieces together. To do that the pieces were attached via lines of material that resemble clothing seams.

This was one of the only tests where all the pieces actually came out as intended, the first time around.

Images 75, 76 and 77 – Biometric Voronoi 3D patterns, samples 13 and 14

5.4.7. The seventh test: sample 8's aesthetic pattern

Because sample 8 came out with a intriguing pattern, the pattern that was supposed to have constituted the base on which the actual piece would have been constructed, I once again asked professor Alexandre if we could recreate the pattern.

The advice given was that we could try to print a solid square with height so we could print the grid and separate them later. For the sake of this test, we went ahead and did it, but after it was complete, although I still enjoy the look and feel of it, I had to admit that if the material that is used for this purpose ends up being one that, unlike TPU, is not recyclable and able to be used for the production of other products, this method would end up wasting a lot of material.

I also must take into account the energy wasted to print this piece when only a small grid was viewed as the finished product.

After this there were no attempts to recreate it using less product and energy though, because even with that obstacle ahead, we believed that I had already learned what I had to from these experiments.

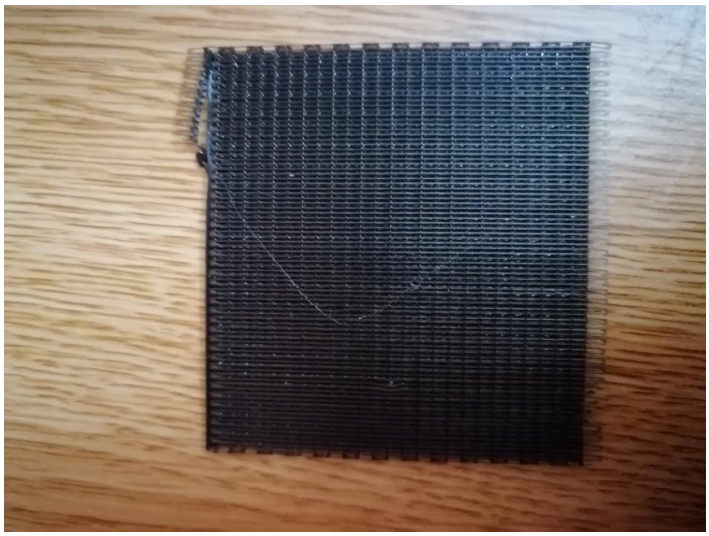


Image 78 – Biometric Voronoi 3D patterns, sample 13

5.5 Discussion

Taking all the tests into consideration I'd say that we're still a long way from being able to print intricate pieces on our home 3D printers without serious knowledge about the 3D printing process and even further away from being able to print large pieces of clothing from our small personal 3D printers.

I'd say though that brands like GUY&MAX and Adidas do have something right when they use the power of 3D printing in their stores to maximize the custom-made capability of the machines. When they do that, they are effectively making the concept of having stock obsolete and that, in and of itself, already helps the environment tremendously. No leftover stock, no waste.

Conclusion

Taking everything discussed throughout this dissertation into consideration we can assume that there is a need in the fashion market for more sustainable options that are both cheaper and more inclusive. Upon identifying this gap, the search for a solution started and 3D printing was to be analyzed as a possible viable fix for this problem.

Although the fashion industry has always had an air of elitism about it and it is, for the most part, one of its most alluring characteristics, I believe everyone should have the means to participate in something they truly enjoy regardless of their body weight and the size of their wallet. The industry would not loose its mysterious and captivating sides just because more people get to be a part of it. It certainly did not lose its "it" factor when the industrial revolution democratized garments for a plethora of future generations. Luxury fashion will always feel just out of reach enough to be the juiciest desired fruit for most people and making fashion, in general, accessible for more people will not kill the temptation.

This might be a controversial opinion when taking into consideration that the fashion world is at best elitist and at worse downright cruel and that this fact seems to be what manages to keep the illusion alive. Like a real-life Wizard of Oz benefiting from a somewhat unearned reputation, only this time, if we click our fabulous red shoes 3 times, we won't erase decades upon decades of societal oppression and dreadful beauty standards that bring upon mental illness to entire generations of young women.

Any way we look at it, beauty standards are harmful. A lot of young humans look up to the good old celebrity or their new favorite online influencer and they are exposed to image upon image of false perfection and engage in the scam perpetuated by society that dictated that they should as well look like that, like people who may have undergone a few cosmetic procedures or full-on plastic surgery and use editing programs on top of that. These young people consume this content and internalize, conscious or subconsciously, that they too must look like that in order to succeed in life.

Fashion unfortunately goes hand in hand with these damaging societal imposed standards. It almost takes advantage of the fact that women are expected to place their value upon our looks, since before we even begin to walk, in order to involve envelop itself in its air of haughtiness, defending its prestige and self-importance more fiercely than Cerberus guards the mighty gates of the underworld.

Sustainable fashion, for all its desire to be perceived as standing on the moral high ground, did seem to take a page of the same book, because fast fashion, for all they do wrong, seem to be the only sector that is currently catering towards consumers with more body fat and with thinner wallets.

It can be argued that sustainability in the fashion industry is still in its infancy as it is a concept that started to be cared about by the masses fairly recently and brands had no incentive to go green as long as money kept poring in. Taking that into consideration, it is understandable that innovation does not come cheap, so sustainable fashion would not come cheap either. But the client and the environment should not suffer for it and 3D printing, although very questionable still when it comes to actually creating useable garments, has the potential of becoming the solution and should be explored as such.

While experimenting with the method, it became clear that there is still a long way to go if we want there to come a time where we simply buy a design online and print it in our own personal 3D printer. While testing in the Pruza printer, there were lots of very obvious obstacles towards that vision.

First of all, there is the size limit. The small and relatively cheap printer, made for personal use, is obviously kind of small and it would take a lot of sessions in order to be able to actually complete a life-size piece. This is even a bigger obstacle when taking into consideration our second hindrance, time.

When testing with the Pruza printer, time was one of the first handicaps encountered. Every single piece, every very small piece, was in construction for about six hours, so constructing an actual garment in a personal small printer would take a gigantic amount of time. This is not even taking into account the times an error would and could occur, stopping and restarting the printing.

In the case of small personal printer, we could be a long way from being able to print whole pieces of clothing, but there are a lot of stores that have the means and space to invest in heavy duty 3D printers and can benefit from adapting to them. This would not only eliminate the need for shipping, but the need to keep stock as well, making the usage of warehouses and the amount of waste from the products that are made and never bought, obsolete.

Brands like Adidas, looking to take personalized content to the next level, are looking towards a future where a client can walk into a store and come out with a customized 3D printed pair of shoes that mold perfectly to that client's foot and brands like GUY & MAX, that have no stock and create personalized jewelry pieces on demand, are proving that it is

possible to go around the limitations of Addictive Manufacturing, while the technology is in its infancy.

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