





Rethinking Textile Disposal: Reuse of Denim for New Product Development

Patricia de Paula Azambuja^(✉)  and António Marques 

University of Minho, 4800-058 Guimarães, Portugal
pati_azambuja@hotmail.com

Abstract. This research proposes to incorporate the process of upcycling textile discards by molding polymers with denim fabric within the polymer matrix to be applied in the development of new products. To this end, according to Bruno Munari (Munari 1981), design should not be designed without a method, that is, thinking in an artistic way with the purpose of a solution is not enough if there is no research on similar projects to what one wants to do. Based on Munari's thought, this article has as its primary step the literature review of what has been explored as well as the study of concepts related to the theme. From this, the selection of possible combinations of materials and technology to be tested was planned, aiming to define, for the second phase of the work (experimental phase), the most viable solution for the development of new fashion and furniture products with denim reuse. In a future phase, this work seeks to develop a material that can be applied in various fields of production, highlighting not only the importance of reusing discarded materials, but also the need for greater awareness regarding the effects of the production mode on the environment.

Keywords: Denim reuse · Circular economy · Upcycling · New product development

1 Introduction

Climate change brings a growing alert and concern involving the impacts of the fashion industry on the environment. Consumers can play an important role in encouraging the necessary changes regarding companies' choice of materials and means of production. As consumers become aware, there is a change in relation to the desired products and companies, and, consequently, a stimulus for companies to seek a more circular economy and sustainable design. As a result, companies are increasingly investing in the development of products that have the least impact possible, and one of the ways is the reuse of materials. The reuse of materials prevents discarded products from reaching landfills and contributes to reduce the extraction of natural resources for the manufacture of new products.

One of the goals of the Ellen MacArthur Foundation, an independent British organization for accelerating the transition to a Circular Economy, is to encourage future generations to rethink, slow down, and redesign a more circular economy. To this end,

this Circular Economy requires businesses and consumers to be able to reflect on their actions, cherishing the preservation of the environment and the resources available for future generations (Ellen MacArthur Foundation 2019). This paradigm shift encourages designers and companies to seek new forms of production involving reuse of materials and development of new materials/technologies.

The United Nations, faced with concerns about production, consumption, and the fate of waste, has proposed the so-called “SDGs” - “Sustainable Development Goals”. To ensure sustainable development while maintaining balance between the 3 pillars - environmental, social and economic, 17 goals were stipulated by the UN and are present in the 2030 Agenda for Sustainable Development. The goals contain a total of 169 targets that have the mission of achieving a better and more sustainable future for all by 2030 (United Nations 2021).

The said 2030 Agenda in pursuit of sustainable development was approved in September 2015 by 193 members. The project is the result of joint work by governments and citizens around the world that aims to create a new global model to end poverty, promote prosperity and provide well-being for all, as well as protect the environment and combat climate change (BCSD Portugal 2021).

According to data released by the Ellen MacArthur Foundation, in order to achieve the goal set in the Paris Agreement of zero emissions by 2050, an urgent change is needed in the production model that has been practiced in recent years. However, even with the determined goal reached it is still estimated that the costs to the global economy related to climate change will reach \$54 trillion by 2100 increasing greatly with each rise in temperature (Ellen MacArthur Foundation 2019).

Sustainability has been a present subject in the academic and scientific fields, and mainly due to the worsening of climate change it has been growing expressively every year. With a greater awareness on the part of consumers and the emergence of some questions about production and use of materials, companies have started to invest in sustainable design and in a production based on a more circular economy.

The 2019 report from the Ellen MacArthur Foundation (Ellen MacArthur Foundation 2019), reports that 73% of post-consumer textile clothing is incinerated or landfilled, that only 12% is recycled in a cascade process, a process in which waste is incorporated into items of lesser value such as insulation material, for example, and only 1% is related to closed-loop reuse, that is, through the production of the same type of item.

In view of this, the textile and fashion area has advanced in investigations involving a less polluting production. For a more responsible performance, within this more sustainable perspective, the textile and fashion industry has been looking for researchers to develop new products from its residues. And more and more designers are specializing in developing products based on textile reuse in order to take advantage of existing materials and minimize waste, preventing products from reaching landfills and consequently reducing the extraction of natural resources for the development of new products.

The management and disposal of waste can have serious environmental impacts, since it must be taken into consideration that besides the landfill occupying land space it can still cause air, water and soil pollution, and incineration can result in emissions of atmospheric pollutants (Eurostat 2021).

Within this theme is the focus of this research, which is directed to the reuse of denim waste from both manufacturing waste from the production chain, but mainly from the reuse of post-consumer denim discard that has as its main destination the landfills.

Textile reuse through upcycling is among the topics that this paper will discuss, contextualizing the experimental process to be developed in other research steps, which includes the process of reusing pre- and post-consumer denim, that is, the reuse of industrial waste and denim discarded by consumers at the end of life. The textile known as denim is widely used by the fashion industry and even after disposal can serve as raw material for various types of products. This study presents a proposal to integrate sustainable design with Circular Economy through upcycling, a process that gives value to discarded material incorporating it in the development of new products and minimizing the environmental impacts of disposal (Morais 2013).

From this, the method developed in this paper begins with a literature review where searches were made for research using denim reuse as well as the study of important concepts. Secondly, an analysis was made of the materials to be considered for testing which include discarded denim and the possible combinations of materials to be tested. Existing denim reuse technologies were analyzed to be considered for future follow-up of this research in a next phase in which to include the testing stage, where combinations of materials and definitive processes in search of a new material will be determined.

2 Methodology

For Bruno Munari (Munari 1981), design should not be designed without a method, that is, thinking in an artistic way with the purpose of a solution is not enough if there is no research on similar projects to the one you want to do. Based on this thought a literature review was made with the analysis of what has already been explored on the subject in question and the study of some concepts related to the theme such as Circular Economy, Sustainable Design and Upcycling.

The methodological structure applied in this first research phase presented in this article is qualitative, where the ways of searching for knowledge are carried out through bibliographic, documental, and exploratory research. The objective is an in-depth search of the literature review and the ways of reusing denim waste that already exist, a search for methods and techniques of reusing pre- and post-consumption waste already developed for the elaboration of new materials and products.

One of the most important concepts within this theme is the Circular Economy. The Circular Economy proposes an economic growth disconnected from the exploitation of natural resources, through the creation of closed production cycles without waste generation and presenting a systemic look in the evaluation of new forms of production and consumption. According to Ellen MacArthur Foundation, adopting a circular economy approach could reduce global CO₂ emissions from major industry materials by 40% or 3.7 billion tons by 2050 (Ellen MacArthur Foundation 2019).

In developing products based on the circular economy, sustainable design becomes an ally for creating designs focused on decreasing environmental impact. According to Manzini, design does not act only on the function or form of an object, design acts on both in the same way, with the awareness that they are independent and with importances

capable of interacting with each other (Manzini 2015). Through sustainable product design, environmental aspects are addressed where the focus is to develop more products and services with ever decreasing use of resources, waste and pollution (Manzini 2008).

Sustainable design, among other concerns, seeks to develop products taking into consideration materials already extracted from nature, which have been used and even after being discarded have potential use.

For a more detailed analysis of this study a review of the bibliography was made through databases, key words such as “waste denim” and “denim dispos” are among those that most identify recent studies. Products and brands already being marketed were also identified in this review phase; there are numerous products already developed with waste. Among the products being developed with the reuse of denim, those considered relevant were selected and established as a basis for the continuity of this research and the material that is intended to be developed.

The eyewear brand Mosevic, Fig. 1, develops fashion accessories using post-consumer denim waste. For the reuse, several layers of denim are placed on top of each other and pressed in molds that are later covered with a special synthetic resin that creates a composite and resistant material called “solid denim” by the company. After all this process the frames for the glasses are cut and stone washed to restore the classic jeans look.



Fig. 1. Mosevic, eyewear brand (Aiken 2016).

In Fig. 2, highlight the denim reuse work of designer Sophie Rowley who creates furnishable objects by reusing denim waste. The products created have a marble-like appearance and represent a lightweight, durable material made from post-consumer denim waste and production waste from fashion industries. The creation of the new material is made possible by layering waste on top of each other and bonding it with a resin. After the material is finished the pieces are sculpted into different shapes and used for internal use.

From the literature review and study of the selected works, having been exemplified in the products above, the investigation proceeds to the phase of analysis of the discarded denim and selection of the possible combinations of materials that will be tested in the next phase of studies (experimental phase).

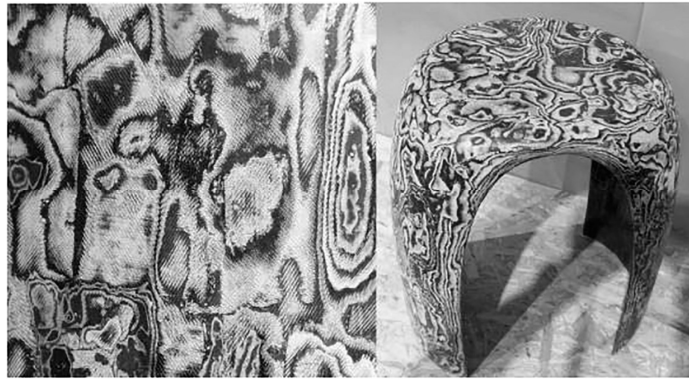


Fig. 2. Bahia Denim, reuse of denim (Hitti 2019).

This research proposes to incorporate the recycling process by upcycling textile discards through polymer molding with denim fabric, the goal is to define the solution through upcycling for the development of new products in a third phase of work. Through upcycling this study makes a relationship between sustainable design and the circular economy, because upcycling is the recycling process where there is an appreciation of the discarded material and does not consist only in the conservation and reuse of materials, but rather in an appreciation that is attributed again to the product preventing it from being discarded (Morais 2013).

Through the exploratory research conducted, it was identified that denim discards, depending on the state of conservation, can be reused in different ways, highlighted for redistribution in second-hand stores, for transformation into new garments or crafts, for recycling with the goal of developing new yarns or for upcycling in the development of new material which is the focus of this research.

Based on the results obtained in the literature review on denim reuse, the techniques, materials and types of products that have been studied were analyzed. After crossing the information obtained it was defined for this study the development of new material through the molding of polymers with denim waste within the polymer matrix. The method was selected since polymeric matrices are one of the most used due to their versatility of formulation and ease of processing, not necessarily involving high pressures or temperatures, thus being simpler and less expensive when compared to ceramic and metallic matrices. The techniques used to develop polymeric matrix composites are being considered with emphasis on RTM (resin transfer molding), a process that uses a liquid thermosetting resin to saturate a fiber preform placed in a closed mold; VARTM (vacuum-assisted resin transfer molding) which allows producing parts with less porosity than regular transfer molding and provides an increase in casting strength (Anon 2022); and COM (compression moulding), in which the material is usually preheated, placed in an open mold cavity, and heated.

3 Analysis and Discussion

In view of the concepts studied and all the works analyzed, the types of products and the development techniques considered most relevant were selected to serve as the initial

base for the experimental studies. From a detailed study, possible combinations of materials were then chosen, which will proceed to the testing phase in search of the best result for the development of the new material. The new material will consist of at least two phases, which differ in chemical and physical properties. Given this, a good combination of polymer, reinforcing fiber and manufacturing process may lead to an application with better properties related to strength/weight, corrosion resistance, among others.

3.1 Denim Analysis

In the analysis on denim, it was observed that this discarded material in its great majority is not made of 100% cotton, denim can present combinations of cotton with elastane and/or polyester. This mixture of materials is one of the factors that hinders the recycling process for the development of new yarn, but that can be advantageous for the development of the new material. A positive characteristic of cotton is that it has thermal and acoustic insulation properties, which can add value to the new material to be developed. Denim also presents good mechanical properties being a very resistant textile due to the interweaving of the weft and warp yarns of its composition (Chataignier 2007).

3.2 Selected Materials

For the next phase of this research, the materials selection and testing phase, the materials to be considered for development into the new material are:

Biomaterials. The use of bioresin arises with the intention of not adding more synthetic materials beyond those already present in most fabric compositions. Natural resins are secretions naturally produced by trees as part of a defense mechanism against aggression. As an example we have the pine resin, in which it presents secretions consisting of a volatile fraction, known as turpentine, and a solid fraction called rosin or rosin gum (Correa et al. 2018).

Among the bioresins to be evaluated is the natural resin of *Pinus Pinaster* present in Portugal, rosin resin is also known as Laurel Pez or Pitch.

Another material to be evaluated because it is considered natural are biopolymers, which is the case of starch polymer, a polysaccharide produced from vegetables such as potatoes. The starch contained needs to be removed, go through a chemical destabilization process and a rearrangement in the molecular structure, which makes it possible to form a material with plastic characteristics.

Discarded Polimers. Like textile waste, plastic material discards are a serious environmental problem.

Polymers and plastics are made up of synthetic macromolecules and can be divided into two distinct groups: thermosetting plastics, which are plastics characterized by not allowing reprocessing and not being able to be melted again; and the thermoplastics that are materials with the characteristic that can be processed many times, and whenever reprocessed their chemical and physical properties are changed, and there may be the loss of mechanical characteristics. The development of thermoplastic polymeric matrix has the advantage of being able to be reprocessed through heating and cooling cycles,

practically without loss of characteristics, an important factor because it promotes the ease of being recycled later. It also presents advantages in mechanical and physical characteristics in relation to thermosetting matrices, such as better impact resistance, for example (Pereira 2017).

The manufacture and use of plastic material, often of single use, leads to an accumulation of waste deposited in the environment without being recycled. Plastic is not a biodegradable material and is considered one of the biggest threats to the environment. About 80% to 85% of marine litter in the EU is plastic, 50% of which is single-use plastics and 27% fishing-related items (CGD 2021). Pollution from polymer use could be minimized by recycling plastics and developing biodegradable polymers. The Ellen MacArthur Foundation's New Plastics Economy project in collaboration with the United Nations Environment Programme is signed by more than 400 global organizations committed to making sure that plastics no longer become waste. The initiative aims to bring forward to 2025 the European plastics targets set for 2030 (Ellen MacArthur Foundation 2022).

Discarded Denim. The denim that will be combined with other materials is a result of discarded by consumers, they are post-consumer products with wear and tear and denim waste from the production process. Combinations will be made containing both types of waste (pre and post consumption) of denim which is a fabric made of 100% cotton (which is a natural polymer) or in combination with other synthetic fibers such as elastane and/or polyester.

4 Conclusions

In this first phase of studies the literature review was done with the study of the important concepts for the theoretical foundation of this research as well as the research on what is being developed involving denim discard and new materials/products. A qualitative analysis that involved the combinations of materials, technologies and types of products in which the material was applied.

From these analyses one can evaluate the possible combinations of materials that have potential to be tested involving discarded denim, aiming to define, in a second phase of the work, the most viable solution for the development of new fashion and furniture products with reused denim by means of a polymeric matrix. Discarded polymers (more specifically thermoplastic polypropylene) were selected as materials to be considered for future tests, to be added to the denim discards because they were also considered to have a great polluting potential as well as textile waste, with the need for both to be reused and removed from the environment. Studies show that pollution from the use of polymers could be minimized with the recycling of plastics followed by the development of biodegradable polymers. The choice of the type of matrix to be used in the next stage has to be made according to the claims of the material to be processed and the applications to which the compound will be subjected. Thus, in this case of creating material for furniture and fashion development (more specifically fashion accessories) it seems that the thermoplastic polymeric matrix is the most appropriate option to be

tested first. Considering that this material can present a solid physical state, higher impact resistance, good durability outdoors, and recyclability, which are important factors.

The processing techniques for the material can be summarized in open and closed mold processes. RTM (resin transfer moulding), a process that uses a liquid thermosetting resin and closed mold; VARTM (vacuum-assisted resin transfer molding) which is able to provide an increase in casting strength (Anon 2022); and COM (compression moulding), which uses a heated mold cavity and was selected as the technique to be used in the next phase of testing.

The literature review of this first research phase was an important factor to deepen the theoretical knowledge related to the theme, to evaluate what is being researched regarding the development of new materials with denim waste, including the technologies applied and mainly to make the decision to start the testing phase with polymer waste (polypropylene) thus focusing on the reuse of two types of discards extremely harmful to the environment.

The objective of this step was to have the theoretical basis to enter the next phase of tests and then the finalization of the material for the proposed development of new furniture and fashion products that should be appropriate to the characteristics of the material developed. The research is focused on the reuse of waste through the development of new combinations and techniques seeking innovation or improvement in the process of denim upcycling.

In the next phase of this research, laboratory experiments will be conducted, the testing of the selected combinations, the analysis of the testing results, and the choice of method and enhancement for testing and final characterization and analysis. Finally, made the creation of the material and depending on its properties, it will then be applied in the development of new furniture and fashion products.

Acknowledgments. This work is supported by FCT - Fundação para a Ciência e a Tecnologia, in the scope of the PhD Research Project in Fashion Design – University of Minho, Portugal.



References

- Kristen, A.: Mosevic eyewear makes. The raddest sunglasses out of unwanted jeans. In: HuffPost Life (2016). https://www.huffpost.com/entry/mosevic-denim-sunglasses_n_57c47693e4b09cd22d91cdb0. Accessed 22 Dec 2020
- Anon: Moldagem por transferência. In: Stringfixer.com (2022). https://stringfixer.com/pt/Transfer_molding. Accessed 24 Mar 2022
- BCSD Portugal: Objetivos de Desenvolvimento Sustentável e o BCSD Portugal. In: Conselho Empresarial para o Desenvolvimento Sustentável (2021). <https://www.ods.pt/>. Accessed 8 Nov 2021
- CGD: O que vai acontecer aos plásticos de uso único? In: Saldo Positivo - Caixa Geral de Depósitos (2021). <https://www.cgd.pt/Site/Saldo-Positivo/Sustentabilidade/Pages/plasticos-de-uso-unico.aspx>. Accessed 10 Apr 2022

- Chataignier, G.: Fio a fio: tecidos, moda e linguagem. Estação das Letras, São Paulo (2007)
- Correa, J.S., Primo, J.D.O., Santos, R.R., Anaissi, F.J.: Resina Poliéster Modificada com Colofônia e Emulsionada por Inversão de Fase. *Revista Processos Químicos* (2018)
- Ellen MacArthur Foundation: Completando a figura: Como a economia circular ajuda a enfrentar as mudanças climáticas (2019)
- Ellen MacArthur Foundation: Plastics and a circular economy (2022). <https://ellenmacarthurfoundation.org/topics/plastics/overview>. Accessed 10 Apr 2022
- Eurostat: Waste statistics. In: *Statistics Explained* (2021). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics. Accessed 9 Nov 2021
- Hitti, N.: Sophie Rowley designs marble-like furniture from Bahia Denim. In: *Dezeen* (2019). <https://www.dezeen.com/2019/03/01/bahia-denim-sophie-rowley-furniture-design/>. Accessed 22 Dec 2020
- Manzini, E.: Cuando todos diseñan, una introducción al diseño para la innovación social. Editorial E, Madrid (2015)
- Manzini, E.: Design para a inovação social e sustentabilidade: comunidades criativas, organizações colaborativas e novas redes projetuais. *E-Papers*, Rio de Janeiro (2008)
- Morais, CC da CP.: A Sustentabilidade no Design de Vestuário. Universidade Técnica de Lisboa (2013)
- Munari, B.: Das coisas nascem coisas. Edições70, Lda, Lisboa (1981)
- Pereira, JM da CR.: Desenvolvimento e fabrico de compósitos de matriz polimérica com fibras naturais. Master's thesis, Instituto Politécnico de Leiria (2017)
- Hazra, S., Bhukta, A. (eds.): Sustainable Development Goals. Sustainable Development Goals Series, Springer, Cham (2020). <https://doi.org/10.1007/978-3-030-42488-6>