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Edited by Marcelo Ambrosio and Carlo Vezzoli

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First Edition

RE-DESIGNING RECOVERED MATERIALS. CASE STUDY: FIBERGLASS IN THE NAUTICAL SECTOR

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ABSTRACT

In the last decades, the relationship between designers and materials changed radically, bringing designers to relate to materials manipulation and production processes. At the end of the twentieth century, the growing attention to environmental issues reduced the choice of materials to those considered sustainable and risking to mortify, together with the materiality, the expressive-sensorial richness of the objects. Therefore, recycled materials have become part of the choices available to designers, foreshadowing new challenges for redesigning their aesthetic aspect and identity. Recently, the dissemination of the maker culture through the Fablabs and the promulgation of the DIY phenomenon, have favorited a rapprochement between designers and materials and their transformation, leading them to enter the interspace between research on materials and their applications. The paper focuses on the experimental research aimed to design new materials experiences and identities which allowed the exploration of new forms of recycling matter recovered from the decommissioning of GFRP boats.

Key Words: upcycling, recovered materials, circular materials, GFRP

1. INTRODUCTION

After the Second World War, the economic boom and technological development gave rise to the belief that the availability of products and materials was unlimited. The "consumer society" has created this illusion of infinite resources. The plastic was the absolute protagonist of this period, being a material with infinite applications and deriving from a material with infinite applications (Fiell & Fiell, 2010). Nowadays, it is clear that the frenetic and irresponsible use of resources available, combined with the accelerated demographic pressure, is no longer sustainable. The linear economy, which characterized the past years following the approach of "producing, using and throw away ", is an economic model no longer convenient, since it could lead to the exhaustion of resources, the increase in prices of raw materials and of waste management in economic and environmental terms.

The transition toward a more sustainable economic, consumption and development model for our society needs a radical transformation in how human society operates and this desirable radical change requires not only technological interventions but also social, cultural/behavioural, institutional and organisational change (Ceschin & Gaziulusoy, 2016; Ryan, 2013; Loorbach, 2010).The long-awaited cultural and behavioural change that can allow the adoption of more sustainable solutions also involves the materials of which the artifacts that surround us are made.

In the field of design for sustainability, we can easily find relevant information and guidelines to use for reducing the impact of materials and materials transformations in the design process (Vezzoli, 2018). What we consider here as useful for our discussion, are the different forms of recycling that, as demonstrated widely, always lead to a net environmental profit. Recycling is defined as the process for converting waste materials into new materials and things. It avoids the landfill, and no virgin resources are used to create new artefacts, generating an indirect environmental advantage (Vezzoli, 2014). In the context of materials for design, it is possible to find easily many successful examples for a specific recycling practice which is more precisely called upcycling. In fact, there are clear distinctions between the various ways we can reuse waste and with the upcycling, we mean the process for adding value to the waste materials and takes less energy to process.

As defined by Sung (2015): "Upcycling is a process in which used materials are converted into something of higher value and/or quality in their second life. It has been increasingly recognised as one promising means to reduce material and energy use and to engender sustainable production and consumption."

We are aware that waste occurs at every stage of the artefact's life, during the design process, both pre-consumer and post-consumer and there is an abundance of wastes and they are usually easily available and cheap. Through creativity, the use of these waste materials as raw materials can be favorited. Such has the benefit of assisting material circulation and reduction of waste in the environment. In our vision, the upcycling design process begins from reassessing waste and follow with adding functionality and aesthetic to the recycled materials (Ahn & Lee, 2018).In the recycling concept in general, the circular approach is implicit, even only at the semantic level and even in the current debate on design the need to move from a linear economic model to a circular model is becoming increasingly evident. Circular economy, as clearly indicated by its name, is an economic model capable of regenerating itself and, as indicated by McArthur (2015), is aimed to redefine growth, focusing on positive society-wide benefits. It is based on three main principles: a) design out waste and pollution; b) keep products and materials in use; c) regenerate natural systems.

Within this framework, materials have acquired great importance and become protagonists in the design of a product in all the phases, requiring particular attention to their origin, their processing and their sizes. In circular economy, the flows of materials are of two types: the biological ones, able to be reintegrated in the biosphere, and the technical ones, destined to be revalorized without entering the biosphere.

The aim of this paper is to present a research and design experience focused on the upcycling of a specific waste and to demonstrate how designers are more and more interested in applying their skills to the development of material from waste, looking at these as resources to generate new raw materials. Today recycled materials have become part of the choices available to designers, foreshadowing new challenges for redesigning the products aesthetic. Recently, the dissemination of the maker culture through the Fablabs and the promulgation of the DIY phenomenon, have favorited a rapprochement between designers and materials and their transformation, leading them to enter the interspace between research on materials and their applications (Rognoli et al., 2015).

This new approach gave rise to a material culture of design in which designers choose to "manipulate" the material through tinkering processes and experiments based on personal experience, collaborating with other experts, leading to the acquisition of new technical-scientific knowledge and creating an opportunity to continue to investigate the relationship between nature and artifice according to the sustainability issue.

In the unlimited number of post-consumer materials or industrial leftovers, fiberglass was very interesting as a case study, because of its difficulty to be recycled for its composition, the environmental impact deriving from the huge amount of material and the high cost of disposal. As it is well-known, fiberglass, GFRP (Glass-Fiber Reinforced Plastic), is made from glass fibers in fabrics or TNT and thermosetting liquid resin which can be polyester- or vinyl ester-based as well as epoxy-based. It is adequately mixed with chemical products (catalysts) allowing its polymerization at ambient temperature. Thanks to its excellent lightness and mechanical properties, as well as its resistance to corrosion and weather conditions, it is used to produce pipes, wind turbines, silos, swimming pools, tanks and especially boats, for which it has been the main material in use since the sixties.

According to a UCINA research in the world, already in 2011 about 75,000 vessels were no longer in circulation, and 54% of these were abandoned, with a presence of about 53,460 tons of waste fiberglass. Also, the amount of fiberglass deriving from old hulls is not without importance: in fact, on the date of this investigation, it was about 148,500 tons (UCINA, 2013).

The nautical industry has not been concerned over time to dispose or recycle used vessels or hulls no longer in use, and only now it is dealing with environmental problems connected with the disposal of the end-of-life products. Current regulations for the disposal of fiberglass are inappropriate and, at the same time, the definition of eco-sustainable integrated production systems is complex from an industrial point of view. At present, disused vessels are delivered to landfills as complex waste with a high cost for those who dispose of them and for the environment. The possible traditional forms of fiberglass re-use are energy recovery through incineration and chemical recycling (pyrolysis), although neither of the two operations is advantageous (Corvino et al., 2016) since material is not 100% utilized: in fact, incineration allows to produce energy only from 27% of waste material and its remaining part is combustion dross; pyrolysis produces about 12% of gaseous substances and 12% of oil substances, and the remaining part is made from solid substances difficult to be disposed.

2. BASIS OF THE RESEARCH

This research has taken inspiration from tests carried out at IPBC – CNR center of Naples, giving birth to Cold Plast patents which allow creating thermoplastic products starting from recycling composite thermosetting materials and expanded polystyrene packaging (EPS).

In particular, ETE (Emulsified Thermoplastic Engineering) process includes the jellification of expanded polystyrene with suitable solvents, followed by the mixing with charges deriving from the grinding of thermosetting composites. This material is obtained in calendered slabs or in pellets so that it can be used in the following processes of thermoforming and injection molding, generally used for thermoplastic materials. The resulting material is a high charge thermoplastic "technopolymer" (up to 85% of charge), which in turn can be recycled, with excellent mechanical and thermic properties. It does not require any virgin material; it is made only from recycled fiberglass and polystyrene which is still, although thermoplastic and therefore recyclable, a relevant part of plastic waste because its recycle is uneconomic. In addition, it is a cold working process through machining, in full compliance with environmental and economic sustainability. Mechanical and physical characteristics of the material deriving from this process can be compared with the properties of fiberglass, both DMC and SMC fiberglass. In particular, in some cases, this material has a resistance lower than the classic fiberglass resistance, whereas its Young's modulus is generally higher and its thermal expansion coefficient is lower. If compared with Corian Dupont, mechanical properties appear to be on average increasingly higher. The resistance of this material is obviously influenced by the percentages of charge (ground fiberglass) and of the matrix (jellied polystyrene).

3. MATERIALS AND METHODS

The procedure described in this issue was aimed at analyzing the perceptive and sensorial aspect of this material, by critically evaluating its effects and re-designing it (Sauerwien et al., 2017). This investigation particularly focused on the perceptive performance of the material surface in terms of Re|Surface with the purpose of identifying the experimentation, in accordance with an immediate reference to the re-design of the material surface and at the same time with the meaning of bringing back to surface, thus evoking both the aim and the object of this study and therefore the recovery of fiberglass from old hulls which re-emerge, through this process, returning in the production cycle. As an alternative to materials included in ETE process (fiberglass, polystyrene, and solvent), other materials were used (ABS, PLA, limonene, carbon resin), by adding marine fillers (seaweeds or mussels), by working in layers or by differently placing basic materials. This experimentation was carried out in IPCB – CNR laboratories of Naples in cooperation with Milan Polytechnic and the University of Campania Luigi Vanvitelli, according to the approach of the Designer in lab, typical of DIY Materials, because, apart from basic material (ground fiberglass), matrices and fillers were recovered and processed in a direct way. Moreover, this procedure can be easily industrialized, with the possibility to create objects of various forms and dimensions in short times, with low costs and different techniques of molding (injection molding, thermoforming, etc.). In addition, this study followed the Material Tinkering approach (Parisi & Rognoli, 2017), based on a Design based critical analysis of tests and the observation of samples.

The design experience for each sample was useful to understand how to manage the process, by addressing modifications to create the following samples. In particular, starting from the basic sample, precise scales of interventions were taken into consideration, that is the selection of ingredients, the management of the process and the expressive applications, through the variation of basic composition, two-color composition, and the addition of marine elements.

This experimentation was carried out by using: a grinder, a planetary mixer, a Carver hydraulic press able to apply an axial load up to 100 kN (having heating plates measuring 15 cm x 15 cm with temperature up to 400°C), a hydraulic press used as an extruder, a vacuum oven. Rectangular steel molds were also used, with internal dimensions of 60 mm x 70 mm, formed by three parts (a frame and two pistons), as well as the equipment commonly used in a laboratory. The experimental procedure for the preparation of samples included two macro-stages: preparation of basic material in the form of pellets and shaping of the sample. In particular, the first stage, that is the preparation of material in the form of a pellet, included: a) grinding of fiberglass to obtain a ground product whose fragments have a maximum dimension varying from 3 mm and 7 mm; b) cutting of the polystyrene to obtain fragments with a maximum dimension of 5/6 cm; c) jellification of polystyrene through the addition of a solvent (methyl ethyl ketone), by using the planetary mixer to uniformly spread treatment; c) mixing of the ground fiberglass and the gel obtained with the polystyrene; d) application of the mix on a smooth surface; e) immersion of the mixture in water to remove the solvent (soluble in water) until the mixture is hardened; f) grinding of the plate in pellet.

The second stage, the shaping of the sample, included: h) setting the temperature of the press plates at 220°C; i) placement of the material in pellets inside the mold; l) introduction of the mold inside the press; m) fusion of material (fusion time about 5 min); n) application of vertical tension by means of a force of 20 kN corresponding to a vertical tension of 4,8 MPa (for about 5 min); o) cooling of the mold through the circulation of cold water in the heating plates (waiting time: about 10 min); p) mold dismantling with extrusion of the sample from the mold. The resulting samples measure 60 mm x 70 mm and their thicknesses are 4 mm or 1 mm.

4. RESULTS AND ANALYSIS

This procedure led to create the first sample with a thickness of 4 mm (basic sample 00), made from 50% of ground fiberglass whose pieces measure 4 mm and 50% of jellified white polystyrene

For assessing the potential of ETE process and of the materials deriving from it, first of all, it was decided to carry out some tests by changing basic composition, without adding other elements. In particular, a first phase involved the modification of the matrix, formed by jellified polystyrene in the basic procedure, using ABS in different colors (white, yellow and blue ABS, derived from disused grinders). A test was also performed with PLA, which is less toxic than ABS, but requires a more polluting solvent for its fluidization. Thereafter, the focus was on charge material, by using carbon resin in place of fiberglass. This material has an intense black color, due to carbon fibers replacing colorless glass fibers typical of fiberglass. Finally, an experiment was carried out on the effect of the solvent modification, by using limonene, which is a natural solvent, and by investigating the olfactory aspect, also to make the process more sustainable. The sample obtained has a color lighter than the sample 00, some transparency of fiberglass fragments and more brightness, probably because during the process, some sheets of Teflon were placed on pistons. The sample is smoother to the touch and gives a sensation of moisture, maybe due to not completely evaporated limonene. The sample has a strong smell of lemon. The use of mixtures with carbon resin and fiberglass charge, both with white ABS matrix, was aimed at obtaining two-color samples with strong chromatic contrast. Two procedures were performed producing different effects. The same procedures could have been carried out using mixtures with different basic colors. The sample of the material showed that the procedure in use does not produce a blending of the two mixtures and there is a definite transition from one to another. But the process does not allow to define geometries of the contact line a priori. In fact, this line is strongly irregular. The difference between the two mixtures is not significant to the touch. This test was repeated with a different percentage of the two materials. A third two-color white-black sample was obtained with an alternative technique. In fact, the pellets of the two mixtures separately produced two thin sheets of 1 mm of monochromatic material. These were then cut in strips with a width of 5 mm and a length of 60 mm. The strips were again placed in the press by alternating a black strip with a white one corresponding to 15 g of the mixture with carbon resin charge and 15 g of the mixture with fiberglass charge. The result was a zebra-stripes material, with a prevalence of the black color.

In order to modify the expressive-sensorial characterization of the material, it was decided to try to introduce additives in the mixture through different procedures, whether the mixture is with ABS or with PS. To keep a reference to sea, some fillers having marine origin were used, in particular fragments of mussel shells or dried Posidonia seaweeds. The presence of “narrative ingredients” coming from other contexts gives the material an impression of depth and diachronic value so that it acquires meaning through the recognition of the element qualifying it.

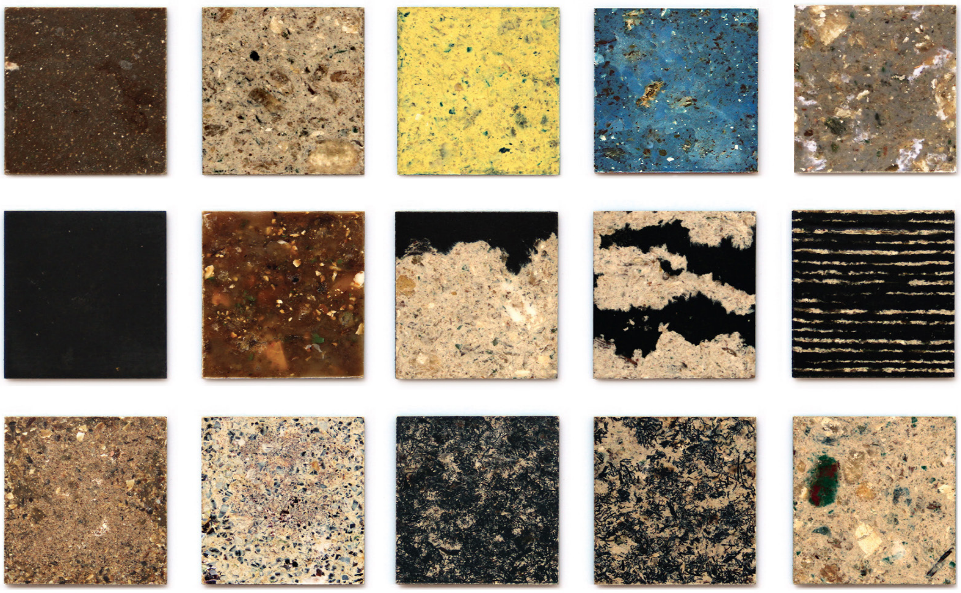
The first experiment was carried out by using fragments of mussel shells. This choice was basically due to environmental reasons and to two different considerations: the intense black color with violet tints that can enrich visual perception of the material and the abundance of this kind of waste both in catering and in the food industry. It should be also noted that, since mussel shells are formed by calcium carbonate, they should not be disposed of in biodegradable waste because not compostable. It must be underlined that in this procedure, after pressing, the fragments of mussel shells are irregularly placed in the thickness of the sample, since the finest pieces are in the lower part. For greater control of the surface texture, it was decided to adopt a different procedure including a double phase of sample molding. The first of these steps is absolutely equal to the procedure of sample 01, made from roughly ground fiberglass and white ABS in percentages of 50% and 50%. In the second step a thin layer of mussel shells fragments (1,5 g corresponding to a surface density of 3,6 g/dm^2) was placed on one of the surfaces of the sample, followed by a hot pressing in the same way, although at a slightly lower temperature (180°C).

This procedure (sample 12) was adopted to create a new sample (sample 13), replacing the fragments of mussel shells with pieces of Posidonia seaweeds collected on the seafront of Naples, always on a sample with the matrix in white ABS. These seaweeds were previously sun-dried and shattered so as to obtain threadlike particles with a maximum length of 1 cm and placed (0,7 g) on the sample with a surface density equal to 1,7 g/dm^2. The resulting sample has a dark irregular design, in contrast with the light color of its bottom. The surface treated with seaweeds is slightly wrinkly to the touch than the surface not treated. This test was repeated by using a lesser amount of seaweeds (0,4 g corresponding to a surface density of about 0,95 g/dm^2) to show the possibility to obtain a different surface treatment according to the fillers. Subsequently, it was necessary to carry out forming trials to investigate the possible working techniques of the material, in order to best understand its potential applications. Some pressure molding tests were performed with different molds, a thermoforming with hemispherical molds of different size and milling through a numerical control machine. Some of these procedures were suitable for working the material since they give satisfactory results. Other tests were carried out to verify the possibility to give the material even complex shapes with very reduced thicknesses (2 mm).

5. IMPACT AND SUSTAINABILITY

These tests showed the versatility of the material which, in the first instance, was ascribed to the marine context, since the resulting samples revealed images recalling visual associations with seascapes, a wave which covers and strongly breaks, or the calm surface of the sea in the sunshine. In addition, it was clear that the material can further be developed, by decreasing colors and textures starting from samples already made. During experimentation, the materials to be used and combined were sometimes chosen according to their availability, in order to work on the visual contrast, directly using samples. The application of marine elements was aimed at "narrating" the connection between the material and a specific context: this does not exclude that also elements of different origins can be added, such as straw, pine cones or any natural fragment or waste, in line with other fields of application. It was found that this material has infinite expressive potential and its combinations can produce many visual and perceptual effects, as well as further tests could explore the olfactory and tactile dimension. It would be surely appropriate to carry out further mechanical resistance tests – particularly bending resistance – and to verify the other properties of the material, such as scratch and grip resistance. It would be also necessary to analyze costs, the observation of regulations, as well as problems concerning marketing and trends, and their possible applications.

In conclusion, this research was aimed at metaphorically revitalize a material which would otherwise "sink" in landfills because non-recyclable, giving it a new life and re-inventing its surface, in order to give it an added value. Nevertheless, it is only the top of an iceberg because there are still many aspects to be analyzed and to be "brought back to surface".



[Figure 1] *Samples in chronological order of realization*

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