Design as a vehicle for using waste of fishing nets and ropes to create new products

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***Abstract*—The world's oceans are full of discarded debris that degrades and sinks or drifts ashore. In 1997, the National Academy of Science, estimated that, per year, about 6.4 million of debris are dumped in the oceans. The debris in the oceans have various origins: sewages, industries, dumpsters and trash left by people on beaches – about 80% of the trash found in the ocean was originated on earth and only 20% derives from marine activities such as fishing. One of the phenomena leading to the entrapment and killing of many animals are ghost nets, which are lost accidentally or deliberately in the oceans usually by fishermen that being pushed by currents can also damage and destroy coral reefs affecting all the marine ecosystem. According to UNEP, it is estimated that there are 640.000 tons of ghost nets worldwide, corresponding up to 10% of the waste in the oceans which represents a big threat to marine fauna. With this paper, it is intended to show how Design contributes to the transformation of marine debris into new raw materials to create new services and products. Currently, there are already being developed solutions to reuse fishing ropes and nets by transforming them into nylon yarn for the production of clothes and carpets. Also *Bureo*, a California and Chile-based start-up, is recycling fishing nets to produce skateboards and more recently, sunglasses. Through this research, it was intended to study the potential of waste from fishing activities and the best way to transform them into raw material, valuing them by promoting sustainable, ecological and economically viable products. After selecting the study subject – reuse of fishing ropes and nets – it was initiated the collection of information and problem analysis to justify the conduct of the research, followed by the collection of the referred waste from *Hidurbe* in Docapesca at Matosinhos's Port to start the respective analysis. Some experiments and tests have been conducted in the Mechanical Engineering Department at Faculty of Engineering of University of Porto to identify the polymers that were picked in order to use the most suitable material for the development of new solutions. Furthermore, an injection molding machine and silicone mold – using human force for compression – was used to know the behaviour of using 100% recycled material. The aim, by creating products from fishing gear waste, is to raise awareness and appeal to recycling in order to contribute to the preservation of marine ecosystem. Design plays an important role in the development of sustainable solutions produced by recyclable waste, extending the life cycle of materials, serving society again.**

Keywords—fishing gear waste; recycled material; thermoplastics; sustainability; design

I. INTRODUCTION

The oceans represent 72% of earth's surface [1] and are endless sources of resources [2] supporting a wide variety of habitats and biodiversity [3]. Unfortunately, oceans are extensively used as a place for waste disposal, of which 80% was originated in land [4] and 20% is related to marine activities [5]. Each year, around 8 million tons of plastic enter in the oceans [Jambeck et al., 2015 cited in 5]. Plastics are durable materials due to its resilient properties that make them persist in the environment for tens to hundreds of years, varying depending on the type of plastic and the conditions to which it was exposed [6]. Although plastics take too long to degrade, after prolonged exposure to wave's action, salted water and solar radiation, they can be fragmented into very small particles, known as microplastic [6] which may be as thin as a human hair [7]. All plastics in the ocean may have a negative impact in marine ecosystem by damaging habitats but also killing marine mammals, fish and seabirds that confuse them with food. The ghost fishing – caused by fishing gear accidentally or deliberately lost which can cause their intake, especially by large mammals and also cause the imprisonment of many marine species [8] – represents approximately 10% of all marine debris [9]. Besides being a threat for mammals and fish, they also may damage and rip coral reefs, introduce invasive species, create diseases, unintended catches and damage to vessels [6, 10]. It is based on these facts that it is imperative to intervene in marine pollution. According to Eriksen, one needs to control the problem at its source, raising awareness for the recovery of plastics and the shift of the paradigm – consume and discard [11]. It is for these reasons that design combined with engineering plays a key role in the search for solutions and in the change of awareness and habits. Regarding this issue, a circular economy should be created, focusing on waste prevention, recycling and reuse [12, 13], reducing the demand for virgin plastic and promoting the demand for recycled products. A different approach during the product development process can lead to solutions using recycled raw materials enabling the extension of life-cycle of materials/products, avoiding the extraction of resources from nature.

A. *Problem Relevance*

As previously stated, ghost fishing represents approximately 10% of all marine debris, due to misdeeds of human being, unconscious or not. In this sense, it is pertinent to intervene with the creation of solutions that encourage the reduction of the abandon of fishing gear and in the awareness of people about the importance of waste as recycled materials, thus acting against the problem of ghost fishing.

B. *Objectives*

With this paper it is intended to demonstrate how design and engineering may contribute to the transformation of waste into new solutions, extending their life-cycle, reducing the need to extract raw materials from nature. It also aims to raise consumer awareness of the importance of the environment and the value of industrial waste.

II. Methodology

To achieve this study it was set the following agenda: collection, identification and testing of fishing ropes and nets (FRN); research of related matter and recycling processes; research of applications of the recycled material in market solutions. All the of these tasks have been carried out at the Faculty of Engineering of University of Porto in Design Studio, Heat Treatments Laboratory and Materialography Laboratory.

A. *Collection, Identification and Testing*

To start this study, *Hidurbe Gestão de Resíduos S.A.* – enterprise responsible for the collection of all waste at Matosinhos's Port – was contacted in order to collect some nets and ropes at *DocaPesca* in Matosinhos.

Fig. 1. FRN collection at *DocaPesca* in Matosinhos.

After collecting and sorting the material by their appearance, its raw material was still unknown. To identify the polymers it was used an identification method of polymers provided by Professor Jorge Lino. The samples and experiments – Table I and Table II – have been prepared in Materialography Laboratory with the guidance of Eng. Emília Soares, which provided all necessary materials. All the different ropes and nets that were identified by their appearance have been cut in small pieces and melted with the heat of a frying pan to create the samples.

TABLE I. Samples Identification

Sample	Identification
A	Blue rope
B	Blue monofilament net
C	Green net
D	Yellow and green net

On the following table are described the tests and results:

TABLE II. Realized tests

	Sample			
Experiment	**A**	**B**	**C**	**D**
Behavior of immersion in water	Floats	Doesn't float	Floats	Floats
Behavior of immersion in ethyl acetate (2min)	Doesn't change	Doesn't change	Doesn't change	Doesn't change
Scratch with finger nail	Scratches	Doesn't scratch	Scratches	Scratches
Behavior after exposure to flame (10gr)	Burns continuously without black smoke	Burns continuously without black smoke	Burns continuously without black smoke	Burns continuously without black smoke
Smoke smell after flame go out	Has not specific odour	Smells of burned horn	Smells of burned horn	Has not specific odour

After analysing the results it is possible to conclude that samples A, C and D correspond to a Polyethylene (PE) and sample A corresponds to a Polyamide (PA). Thereafter proceeded to the transformation of the identified materials. Firstly, some experiments – Table III – were made with a vertical injection molding machine using materials A and D, both polyethylene. The materials have been previously crushed and injected with a pressure of 2MPa into a small mold – Figure 2 –, which belongs to the Mechanical Department. The results were:

TABLE III. Experiências na injetora vertical

Experiment	Material	Temperature	Pressure time	Behaviour on injection
1	PE (D)	170ºC	5 sec.	Very viscous
2	PE (D)	200ºC	7 sec.	Very viscous
3	PE (A)	215ºC	7 sec.	Very viscous
4	PE (A) + 30% PE virgin	215ºC	10 sec.	Injected but didn't fill the mold
5	PE (A) + 60% PE virgin	206ºC	6 sec.	Injected and filled the mold

Fig. 2. From left to right: experiments 1, 4 and 5.

With the performing of these experiments it was verified that recycled PE from FRN has a high viscosity, not allowing the flow of the material through the sprue bushing, having never filled the mold. However with the addition of virgin PE – which had much lower viscosity comparing each other – it was possible to fill the mold with, approximately, 40% of recycled PE – Figure 2, experiment 5. Note that the mold sprue bushing has a very small diameter, not being the most suitable for the material.

In the second experiments, it was used a silicon mold of a cup where it was placed melted material to give shape using human force as pressure. As can be seen in Figure 3, experiment 6 had lack of material to fill the mold. In the second cup, it already filled the mold. However, this molding method has proved to be unsuitable due to the high viscosity of the material because the samples having some defects.

Fig. 3. Silicon mold of a cup; Experiment 6 and 7.

B. Literature Review of Ocean Debris

After the completion of the experiences and the encountered difficulties, more research was done to know if it is a viable solution to use 100% recycled PE for injection molding. Upon the research, it is known that recycled High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE) changes the melting behaviour and reduces the crystallinity of the material, being the major changes in the structure of the material after reprocessing [14]. Since PE is stable, degradation is significant only after a number of reprocessing cycles [14]. 100% recycled HDPE features a reduction of 20% in their mechanical properties comparing to virgin HDPE [15]. In another paper, hemp fibres incorporated in virgin and recycled HDPE, concluded that the recycled HDPE composite has a better performance than the other composite with virgin HDPE [16].

Two enterprises – *Aquafil* and *Bureo* – that use 100% recycled material for their products were also analysed. Firstly, *Aquafil Group*, founded in 1969 and a global leader in the synthetic fibres industry, created the *ECONYL® Regeneration System* [17]. *ECONYL®* is a Nylon6 100% regenerated fibre produced from waste as FRN, carpets and cloths, transforming it into a 100% recycled and recyclable yarn with many possible applications [18]. *ECONYL®* has two types of yarn: Bulk Continuous Filaments (BCF) that can be used in the production of carpets, upholstery and some automotive coverings; and Nylon Textile Filament (NTF) that can be used in the production of clothing such as underwear, sports clothing, swimwear and socks [19]. There are some brands/enterprises that already use these yarns for their products, as for example: *DESSO* created *AirMaster* collection which has tapestry with more than 50% of *ECONYL®* yarn [20] and also tapestry from *Interface* in *Net Effect* and *Human Nature 2014* collections [19]; *Koru Swimwear* [21], *Arena* with their new collection of swimwear *Waterfeel X-Life* and *Adidas* in 2014's swimwear collection [19]; and *Star Sock*, which owns brands like *Lotto*, *New Balance*, *Healthy Seas Socks*, *Dakar* and *Jack Brent*, is producing sports socks [22]. *Levi's* is the first case of using *ECONYL®* yarn in jeans [23]. Secondly, *Bureo* conceives innovative solutions to the growing problem of plastic pollution in the oceans by developing products with sustainable design such as skateboards and sunglasses [24]. In an email conversation with a co-founder of *Bureo* was possible to confirm that they only use 100% recycled granulate of fishing nets, being Nylon6 the main used polymer but they also use Nylon6,6, HDPE and Polypropylene.

Moreover, in 2015, *Adidas* in partnership with *Parley For The Oceans* created sneakers made of plastics and fishing nets from the ocean [25]. *Bionic®* is a materials engineering enterprise dedicated to the manufacture of high performance yarn by using plastics recovered from coastline [26]. *Bionic®* yarn is already implemented in the *GreenScreen Sea-Tex* – the first solar control fabric made of recycled plastic – by *Hunter Douglas* [27], as well as in the project *Raw For The Oceans* – clothing collection designed by Pharrell Williams in partnership with *G-Star Raw* [28]. More recently, *VolkerWessels* is developing a road made of plastics from the ocean – PlasticRoad [29]. This prefabricated solution provides an easier and faster application but also is the ideal sustainable alternative to conventional road structures [30].

III. Project – Material Application

In order to enhance the recycled material from FRN, the project aims to create a product to be used on beach while keeping the connection to its origin – the ocean. It is intended to develop a beach "bag backboard" that allows to the user to enjoy of two functionalities in a single product by being able to carry his belongings and at the same time having a comfortable backboard on beach.

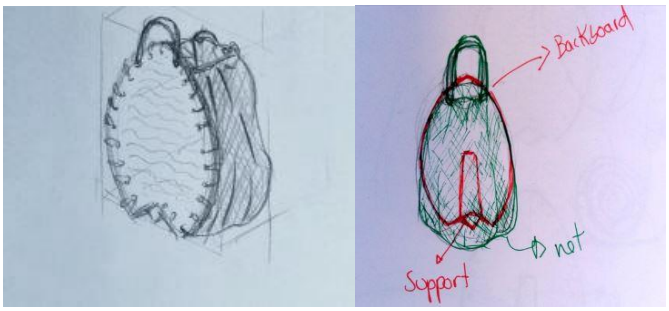

Fig. 4. First sketches of the bag backboard.

When designing the "bag backboard" it was decided to use the recycled material from FRN in three ways in order to take advantage of polymers abilities. Thus the bag component will be made using fishing net in its natural state allowing the sand that is always accumulated in towels and objects, as toys, to fall off. Inside this component, there will be a small room in fabric made of nylon from fishing nets, so that the user can place smaller belongings with more value to ensure their safety. The last component is going to be the backboard made of recycled PE from FRN by injecting recycled PE pellets in an injection molding machine. This product is being designed for people who want to go to the beach and have a place to abut while reading a book, having a drink or just to rest, so it must be ensured comfort as much as possible. Due to the significant variations of human body size, this "bag backboard" is also being designed taking into account the existing anthropometric data of population from the book *Human dimension & interior space: A source book of design reference standards* of *Julius Panero* and *Martín Zelnik*. Considering this, percentile 95 is going to be used in order to cover the majority of the population avoiding discomfort when using it [31]. However, due to the dual functionality of the product, it was necessary to adjust some measures ensuring that transport of the "bag backboard" does not become uncomfortable not compromising the performance.

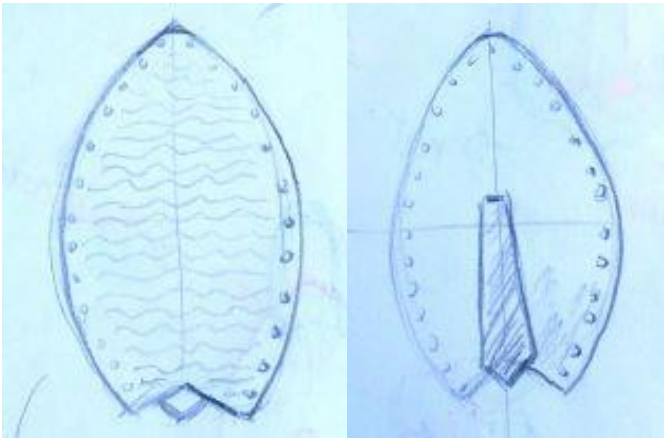

Fig. 5. Backboard inspired in the shape of a fish. Left image: front view; right image: back view.

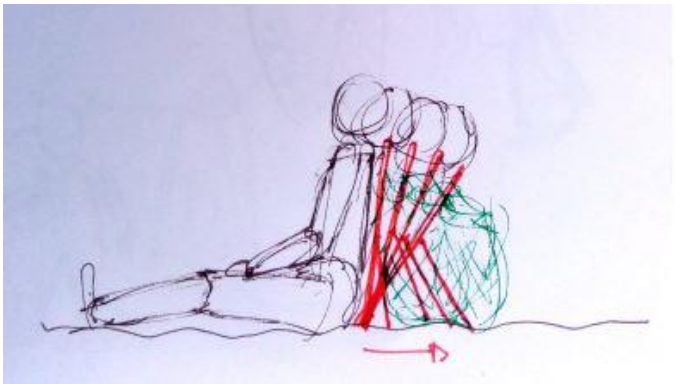

Fig. 6. Inclination studies for the backboard.

IV. Results and Discussion

Although the performed experiments with 100% recycled PE from FRN have not been positive neither conclusive, with the literature review it was found that using 100% recycled FRN and others is a real possibility depending on the application. However there is still uncertainty about the available information on the mechanical properties of recycled polymeric materials due to the wide variety of polymers and additives in products as well as the wide possibility of materials exposure during the life-cycle of products.

V. Conclusions

With the completion of this paper it can be concluded that the recourse to recycled solutions, for example, using FRN, as new raw material can be an excellent alternative in the design of products, creating more sustainable and still aesthetically pleasing solutions, avoiding the extraction of resources from nature. It was also found that there is a growing concern in cleaning the debris of the oceans and use the possible debris as raw material for new products. After the performed experiments in this study, there is still a need to go further in order to obtain a better analysis of the ability of the material to be injected.

VI. Project Limitations

There were some limitations during this study in the available tools to carry out the processing of the material properly as well as the respective experiments. However, the project is still in development not being possible to present more results at this time.

VII. PFuture Development Prospects of the Study

It is intended to create a new injection mold of a more appropriate object with a sprue bushing with higher diameter to perform more experiments with the material in order to get new answers about the ability of the material to be injected. In addition, it is intended to try to define the required characteristics for a small injection mold to be used in the provided injection molding machine taking into account the recycled material used. Thus, it is expected that in the future may encourage students to use the machine more frequently in faculty with recycled materials instead of virgin material.

Finally, the performing of a 1:1 scale prototype is desired to able to proceed to usability testing.

Acknowledgment

Thanks to *Hidurbe Gestão de Resíduos S.A.* for supplying the waste of FRN and also to *Cruz&Cruz* – manufacturer of fishing nets – for allowing a visit with guidance. Thanks also to the Mechanical Department of the Faculty of Engineering of the University of Porto for all the provided support with a special acknowledgment to Eng. Emília Soares for all the collaboration and support provided.

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