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DESIGN CONSIDERATIONS UPON PRODUCT END-OF-LIFE OPTIONS

Abstract: *The paper presents some considerations about the necessity of evaluating the environmental impact of a product during its entire life. The present situation (economic, social and ecologic) imposes solutions to reduce this impact as a result of an analysis performed during all stages of the life cycle. This paper focuses on design solutions with consequences in the last stage, the end-of-life. Reusing products, with, or without remanufacturing and recycling the materials from products that cannot be reused represent some options analysed in this paper. The end-of-life options should be known even from the beginning of the design process and should be included as design objectives or, at least as constrictions. Considering them as human needs would naturally include them in the requirements list.*

Key words: *design, life cycle, end-of-life, reuse, remanufacture, recycle.*

INTRODUCTION

Today, the problems connected to the subject of environment quality are of major importance and fulfilling the sustainable development objectives put pressure on design and designers as well.

Design can play a major place in improving the environmental performance of a product. The necessity to evaluate the product along its entire life is now compulsory. Different instruments are available for evaluating the product in each of the five stages of its life cycle [6]. Life cycle assessment (LCA) became a *way of thinking* [5] for all those involved in product design, fabrication and transportation. All users should follow this trend because there are still many situations of products incorrectly exploited having as a result an increased negative environmental impact. Also, users are responsible for the existing situation in the end-of-life stage, as out-of-use products are not collected for a useful life extending, and are simply landfilled.

Consequently, the last stage of the life cycle of a product, the end-of-life, will be analysed as follows, as a potential source for optimization. As a result of the product assessment, the product design should be improved as concern its durability, assembly solutions or use specifications. The end-of-life options should be included as one or more constrictions in the design process. Legislation, peoples' education and attitude, and last, but not least, the product design could be improved in order to meet the goals of sustainable development as concerns the last stage of the product life cycle.

2. THE PRODUCT END-OF-LIFE OPTIONS

In its early stages, the design process involves establishing the objectives and the constrictions necessary for the optimum solution finding. According to the company objectives and depending, among others, on the type of product and its usability, designers have to choose between several objectives regarding the product end-of-life (Figure 1) [3].

Increasing the *product durability* which results in producing less waste can send the end-of-life far away, somewhere in the future. Also, globally, less material, energy and possible less work is involved. However, the useful life of a product can be extended using probably more, better or/and more expensive materials for each product unit. These materials might require more expensive or energetic intensive technologies, using more complex tools and higher qualified workers.

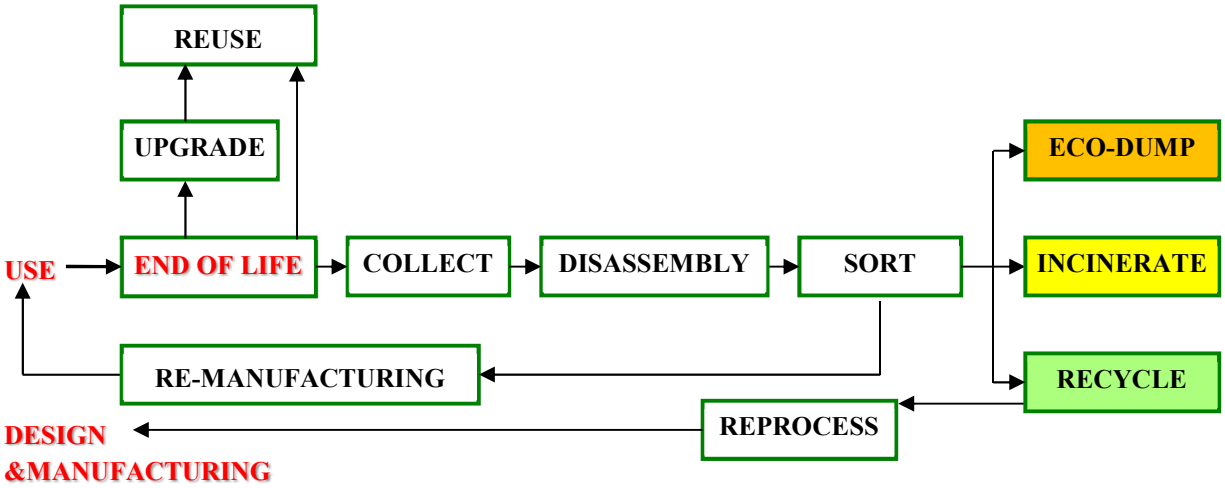

Fig. 1 Product End-of-life options.

No matter how long their life span is, at certain moment products reach their end-of-life. Several options are available and designers should have a decision in accordance with the information about the product complete life cycle. When the product belongs to a category with a fast development in materials or/and technology probably durability is not the best option. Better options could be reuse with upgrade or remanufacturing. Reusing the product as it is can be a better option with a nearly zero negative environmental impact. When the products cannot be reused recycling is the next best option. It is a good solution because it permits the recovery of useful materials that can be reprocessed and included in new products. What cannot be recycled should be verified against toxic substances and burned into special incinerators to recover some energy. When all the previously presented options are not available the last option remains to deposit the waste into environmentally safe landfills.

The above end-of-life options and a clear hierarchy of them should be known by designers even in the early stages of the design process. Today, we consider that the design objectives should include that which refers to the environment protection, thus the designing of any product should be in fact an *ecodesign* process.

Consequently, the ecodesign is a design process having as objective the reducing any type of negative impact upon the environment. Other objectives are subordinated to the main one, and they are mentioned using collocations like Design for Assembly and Disassembly, Design for Maintenance, Design for Upgrading, Design for Recycling, and others similar. At the same time, other constrictions related to reliability, safety, ergonomics, functionality, remain also important and the solution should be a compromise one, fulfilling all the objectives and respecting all the necessary constrictions.

3. THE PRODUCTS REUSE

The product can have a longer or a shorter life according to its usability. Package is an example of industrial products that have a relatively short life, becoming waste very quickly. Thus, increasing product durability represents a design option, but which does not involve the end-of-life options.

By far, the best option for products ending their useful life is reusing the products. The essence of this option is to extend the useful life of a product beyond the estimated life-span, usually with a changed functionality. Car tyres is a good example of product reusing without any modifications or improvements; they can be reused for fulfilling the same function (Figure 2,a), or a different one (Figure 2,b).

Product components can also be reused as individual products with the same, or fulfilling different function(s). Car engines can be used in "scrap-made" vehicles or for producing electricity in remote places.

A different version of this option is the product reusing after upgrading. Upgrading is different from re-manufacturing because it can be performed by the user. The design solutions should permit this action which means that the new parts with improved characteristics must fit into the old product. As long as the new components can be parts of some new products, it is necessary that the connectivity, assembly and fitting solutions to be identical. They should be assembled as an usual spare part, with simple, universal tools. In this way, these "old solutions" become design constrictions in the embodiment design stage of the new product.

The design should anticipate the product reusing, as a whole, or only parts of them. Also, the components susceptible to be reused should be identified and design the possibility of disassembling for reusing – no parts of the assembly to be damaged during disassembling process and use simple assembling solutions.

a.

b.

Fig. 2 Reusing the car tyres.

The most significant example of products that can be upgraded is computers. They are a *role model of Design for Upgrading* which is another constriction to be considered during the design process whenever necessary. Usually, the personal computer can be disassembled and components can be removed using a simple screw driver and with bare hands. Thus, it is for sure that changing a component for repairing or upgrading the product was anticipated by the designer even from the conceptual design stage and followed up in the embodiment design stage.

Designing products for upgrading is a good situation accepted both by the purchaser and the producer. The first one appreciates the money saving solution and the companies should promote the material saving as an environmentally friendly solution. For the companies it can be a way to keep the customers as they should upgrade the products using new components produced by the same producer.

4. THE ADVANTAGES OF REMANUFACTURING

Remanufacturing represents a combination between reusing and recycling. The out-of-use products are collected and disassembled. The components that are in good condition should be reused i.e. cleaned, refurbished and then assembled into "identical to new" products. The

reused components are usually combined with new components to result a product which is identical to a new product as concerns functionality and aspect. The components that cannot be reused are replaced with new ones, and those that are broken, damaged, or depreciated are sorted and sent for recycling.

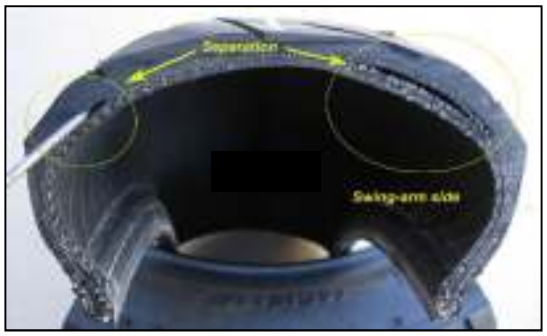

Fig. 3 Used tyre remanufacturing. [8]

The remanufacturing activity consumes time and resources, but considerable far below the necessary amount of resources for a totally new product. The advantages of remanufacturing are obvious, as the Automotive Parts Remanufacturers Association (APRA) cites data from the prestigious German Fraunhofer Institute showing that the worldwide effects of *energy savings due to remanufacturing* exceed the equivalent of 10.7 million barrels of crude oil [10]. The same source mentions that "*substantial elimination of solid waste generation and atmospheric pollution*" has been recorded.

Remanufacturing is an option that was first introduced in industry for machine-tools, cooling and heating devices, or jet engines. In time, the procedure extended to home goods like refrigerators, toner cartridges or gas meters. The above mentioned automotive association is a very active entity with remarkable results. The car parts that can be reused, or refurbished and then reused represent a significant saving factor as concerns materials and energy inputs on one hand and waste and emissions output, on the other hand. Car batteries and tyres (Figure 3) are some of the most remanufactured components. This solution is a positive one because as a waste both components have an extremely high negative impact for the environment.

Design search for solutions for more products to be possible of including in such procedure because of the advantages: reduce materials and energy inputs, reduced waste and landfill. Additionally, the remanufacturing process involves used products recovering and dismantling into an industrial environment. The components that can be reused are separated, then cleaned and refurbished; what cannot be reused is sorted and sent for recycling. Thus, remanufacturing helps the process of materials recycling.

5. THE MATERIALS RECYCLING

Recycling represents an option for the out-of-use products in case they cannot be reused. Useful materials are collected and reintroduced into the process. The major advantage of recycling is raw materials saving and reducing the ecological footprint [3] corresponding to virgin materials obtaining and processing. In many cases, recycled materials have the same characteristics as the new ones [2].

Fig. 4 Using recycled materials represent an important objective in automotive design-for-recycling. [9]

The recycled entities have two major sources (Figure 5): production, and used products [1][2]. The first category is considered recycling of level 1, and the second, of level 2 [1].

Recycling the waste resulted during the fabrication of the product, means introducing it back into the process (e.g. rejects, off-cuts, cuttings etc). Recovering the waste from fabrication and reintroducing it into the process is simplified by the fact that waste is already sorted and can be reprocessed in the same company.

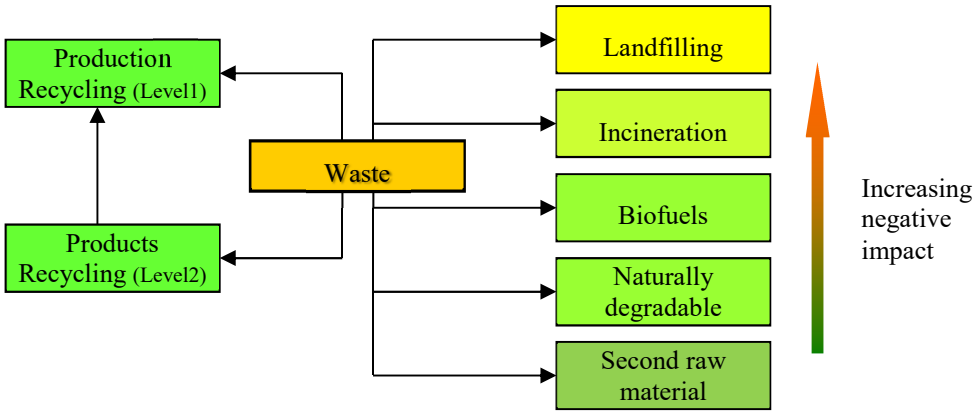

Fig. 5 Materials recycling and other product end-of-life options.

Optimization in this case involves product design and technology design. Designing forms that are technologically sound can reduce the first level waste.

From the design process perspective, the recycling of the second level is to focus on. *Change* is the key word for designers in order to reach the ecodesign goals.

The first to be changed is their *mentality* and the *design thinking* [4]. The approach in the design process should be changed even from the early stages when the requirements list is built. The objectives hierarchy should be changed and the constrictions related to the environment should be "pushed" forward. The *structure of functions* on one hand and the *working principles* and the *working structure of the solution* on the other hand should be re-analysed to permit the new constrictions fulfilling [2]. The working structure is the starting point for the *construction design* stage when the concept becomes project by establishing dimensions, materials, and fabrication methods. Therefore, this should be the starting point for implementing a "*recyclable solution*".

Recycling as an important option for the out-of-use products and involves finding solutions, some as general recommendations, and other as specific ones. Simplicity as a general design principle [3] involves reducing: number of components, number of materials, size, mass, volume; also means simpler shapes, simpler assembling systems (fasteners and joins [7]), and for products, ease of operating, improved accessibility, reduced time for assembling-disassembling and so on. Simplicity might ensure the economic feasibility. A small number of components and elementary shapes can be produced more easily and rapidly and statistically the probability that some components deteriorate is reduced.

Specific design factors are related to product life-span i.e. how fast the product becomes a waste, or related to the domain where the product is used, or the human object-group behaviour. Knowing these factors and their influence on product use involves performing a professional research and build a solid requirements list.

Other options are available for the out-of-use products. Using degradable materials makes recycling obsolete. Usually this category of materials is good for packaging. Natural materials can become second raw materials and can be reused for the same products, or different ones (e.g. wood).

Incineration reduces landfilling but destroys almost all materials for good (metals could be saved during this process but unsorted is hard to recycle). There is some energy recovered by this process, but burning materials results in some emissions and solid waste (ashes). For these reasons, design solutions should exclude these options that brake the materials cycle.

6. CONCLUSION

Design can determine the product out-of-use options. Designers only have to choose correctly the design objectives and their right order of importance. These will determine the working structure of the solution or the concept design permitting a construction that will permit the intended road when the product ends its useful life.

The end-of-life stage can be a new beginning for products through reusing or upgrading. Remanufacturing represents a mix of reuse and recycle and is the best option for now because most of the products present a difference of reliability between the various parts of the ensemble; consequently, the components will wear uneven and will not brake all at the same time.

Using recycling materials should be completed with other constriction to complete fulfilling the ecodesign objectives. Recyclability requires product collecting, disassembly, sorting with the condition that design solutions to permit the above mentioned steps.

Only in case recycling is not possible, the waste should end in incinerators or ecological landfills.

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