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Considerations about Reducing the Environmental Impact in the Product Using Stage

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Abstract

The product environmental impact during its useful life will be analysed in this paper. Some products consume significant resources when used and others consume small amounts, even none. Designers should assess all the products and establish the weight of energy and materials consumption during this stage from the total. Usually, this evaluation is performed using assessment instruments like LCA. In this way, designers can improve the products and reduce consumption and waste during the use stage.

1. Introduction

A product life cycle consists in five main steps, as follows: raw materials obtaining, product manufacturing, transport and distribution, product use and product end-of-use [1]. Eventually, the product can be recovered and in this way, some possibilities may occur: reusing, re-manufacturing, refurbishing or recycle the whole product or parts of it.

Design can influence the environmental impact of a product in many ways and many points of its life cycle. As generally assumed, a product impact should be first assessed and then designer must think about the most appropriate measures to be taken. These are two of the three steps of a typical Life Cycle Assessment (LCA): inventory, evaluation, optimization [1].

For the designer, when creating the products, the order of priorities should be the following: durability, upgradeability, reuse, recycle, energy recover and disposal. The significance of the above list is that design for environment puts on the first place the extension of the product's life through *durability and upgradeability* (i.e. extending the product *useful life*). There are indicators that consumers are more ready to throw products away for reason of fashion or minor damage.

Therefore, the useful life of a product can be extended through durability, but also by simplifying the product, which means a simpler structure with fewer components and which is easier to *repair and maintain* [2].

2. Useful life of products

When considering the environmental impact, designers are tended to concentrate on the raw materials obtaining, manufacturing and disposal stages and give less attention to the useful life stage. This can be correct for some products (e.g. hand tools, furniture, books), but for other category of products (e.g. domestic appliances, vehicles, office machinery) it might be the use stage that causes the most environmental damage and therefore this deserves a special attention.

There are also other categories of products, which have little direct environmental impact in use, but which can cause indirect problems. For example, clothes have no impact when used, but washing or dry cleaning them is usually damaging for the environment.

We are going to analyse the second and the third category of products for which the environmental impact in this stage is quite significant. Heating and cooling appliances, cookers and washing machines, refrigerators and freezers, computers and TV sets, light devices, all cause the larger environmental impact during their useful life (see Figure 1). In case these products consume not only energy but also other materials, or water (e.g. besides the energy, washing machines consume detergent, additives and large amounts of water), then the importance of the usage stage becomes even greater.

A life cycle analysis performed for a washing machine over all five stages: raw materials extraction, manufacture, distribution, use and end-of-life/disposal, would permit us to observe the environmental impact

Keywords: *environmental impact, life cycle, products*

caused in each stage concerning energy consumption, air pollution, water pollution, solid waste and water consumption. The results make evident that the overwhelming proportion of the impacts come from the washing machine usage stage, not from manufacturing or disposal ones.

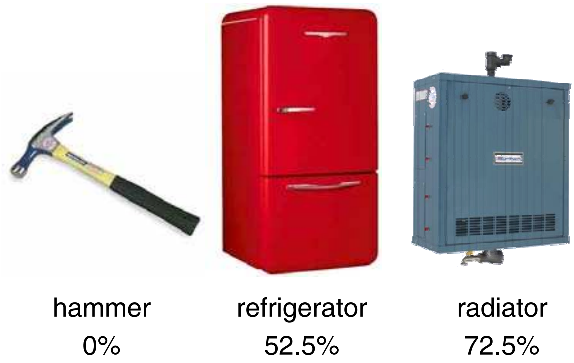

Figure 1. Useful life costs as a share of total product lifetime costs

In environmental terms, the materials and processes used to build a washing machine, the way it is packed and transported, and whether it is recycled or not, are almost irrelevant compared with how it performs during its use.

Designers have a crucial role in reducing the environmental impact of products. Most probably, if a product is friendlier for the environment it will be more expensive [3]. Therefore, customers should be informed about the environmental performances of the product and eco-labelling is a first step in this direction. For the washing machine in the above example, the difference in efficiency between the best and the worst product is significant, with the best using maybe half the water and energy of the worst.

3. Case study: washing machine

Significant improvements in environmental performances of a product can be achieved through innovation. Of course, the benefits from greater efficiency are felt not only in the environment but by the consumer, too. If a washing machine or any other electric device consumes less water and less energy, this is good for the environment, but also for the customer who will pay less during the useful life of the product. In this way, if properly informed, people can freely choose to pay more when buying the appliance and save significant money every time they use it.

Speaking about innovation in the washing machines domain, the idea of recycling the water represents a good example for reducing the environmental impact. Using less water (by recycling it) and finally evacuating a quasi-clean water is an important step towards improving the environmental performances of this product. This innovative idea will lead to a structure of functions, which will include a new one: recycling the water.

In any product, energy, material and information are listed as possible flows (Fig.2) [2][4]. The conversion, which must be defined in quantitative, qualitative and economic terms, is known; the task of function is described based on inputs and outputs. Usually, one flow is prevailing, but in any situation, a small flow of energy is required. In the case of a washing machine, the main flow is material; the energy and information flows are also present.

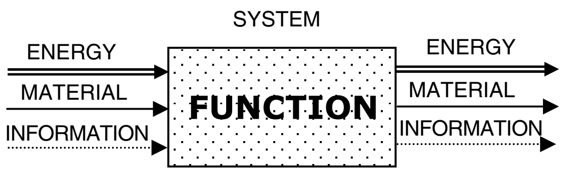

Figure 2. The conversion of energy, material, information.

The overall function for such a product is to convert an input of dirty laundry into an output of clean laundry, as shown in Figure 3. Inside the "black box" there must be a process that separates the dirt from the laundry, and also the dirt itself must be a separate output.

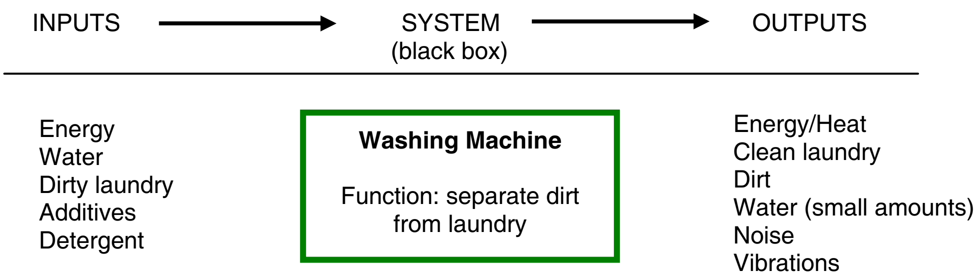

Figure 3. Task of function for a washing machine, description based on inputs and outputs.

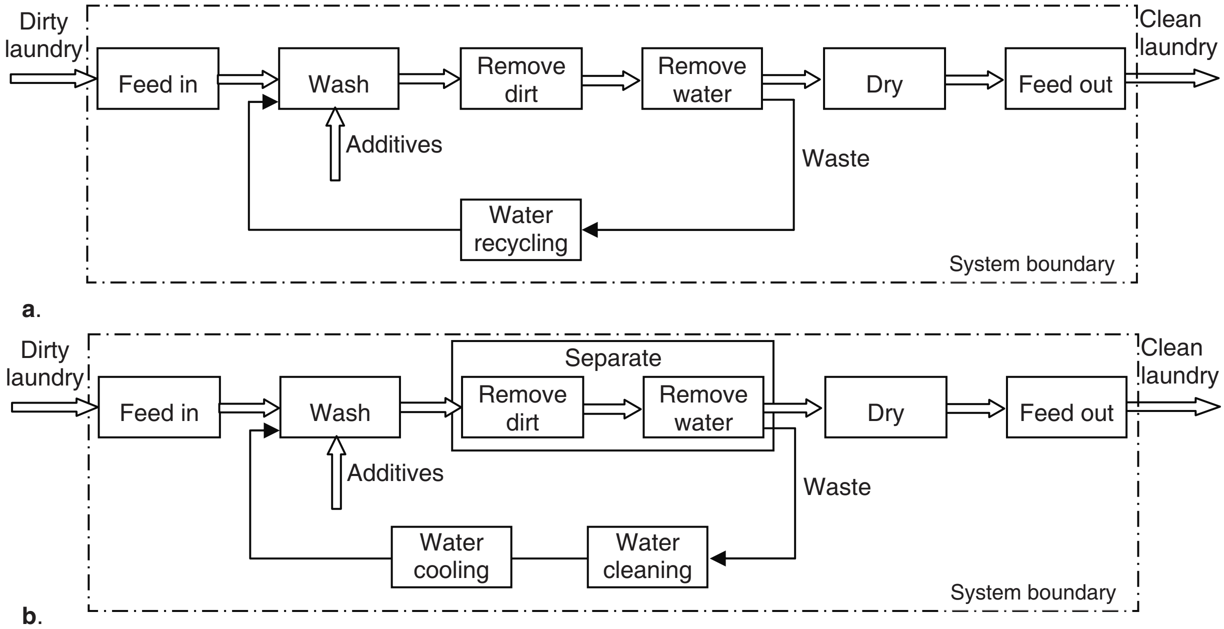

Figure 4. Function structure for the washing machine.

It is known that the conventional process of cleaning the laundry involves water as a means of achieving this separation, therefore our goal is reducing the water consumption.

Figure 4.a presents the structure of functions for a washing machine having included the new function: water recycling. This new function will require the existence of a system capable to purify the water and probably to cool it before being drained. In order to purify and cool the water some auxiliary functions are required; they also will be positioned inside the material flow. The next function structure, presented in Fig. 4.b, includes these two auxiliary functions necessary to fulfil the requirement regarding the water recycling. The process of creating the function structure is an iterative one. Therefore, changes can be performed until the end of the conceptual design stage, and even in the embodiment design stage.

The new functions introduced into the structure, even they are auxiliary ones, require designers to find solutions. Like the main functions, the auxiliary functions are usually fulfilled by physical, chemical or biological processes. A physical process fulfilled by the selected physical effects and the determined geometric and material characteristics results in a working interrelationship that fulfils the function in accordance with the task.

In this case, the water can be cleaned up using physical (filtration, decantation), chemical or magnetic separation. The temperature can be decreased by radiation, heat transmitter etc. using an adequate geometry, and choosing solutions compatible with the existing ones, designers can conceive a more complex and complete product. For this situation, the criteria used to evaluate the solutions should include those regarding the environmental impact.

Several physical effects may have to be combined in order to fulfil a function; also, a number of functions can be fulfilled by a single physical effect. For a washing machine, two functions, rinse and separate, can be combined in one, without affecting the quality in fulfilling the functions (Fig.4.b).

Therefore, being more complex (two additional functions), this product will be more expensive than the usual ones, which do not recycle the water. Consumers should be informed about the advantages and disadvantages of the product, about the costs and payback and have a free purchasing option. Continuing to improve the project, designers can find solutions to reduce the costs, in order to compensate supplementary investments caused by the new function. For example, they can reduce the water used by improving the efficiency of the washing process, or can reduce the energy consumed by recycling some hot water.

4. Product maintenance and repair

Technical systems and products are subjected to wear and tear, the useful life reduction through corrosion, contamination and changes in time-dependent material properties. After a certain period whether in use or not, the actual condition of a system will no longer be the intended one. Deviations from the intended condition cannot always be recognised directly and can cause changes in performance, failures and dangerous situations. This can reduce substantially the functionality, economy and safety and can influence the relationship between the product and the environment.

Because systems and products have become more complex, maintenance, as a preventive measure, has become increasingly important. Thus, designers have a significant influence on maintenance costs and procedures through their selection of the principle solution and embodiment features (established in the previous phase).

Usually, maintenance is related to safety, ergonomics and assembly. But, maintenance can affect the environment either directly (emissions, waste), or indirectly – by affecting the product functionality.

Maintenance involves monitoring and assessing the actual condition of a system and maintaining or recovering the intended condition. Possible measures are the following [5]:

- Service – maintaining the intended condition;
- Inspection – monitoring and assessing the actual condition;
- Repair – recovering the intended condition.

The maintenance strategy is influenced by the rate of deterioration of components, for example through wear that reduces operating life. The measures to recover the intended condition have to be taken before components are predicted to fail. Accordingly, two types of repair are distinguished:

- Preventive repair that takes place before components fail; this can be either determined by interval/time, or by condition;
- Failure repair that takes place after a component has failed.

Maintenance requirements should have been included in the requirements list. When solutions have to be selected, easily maintained variants should be preferred. Examples are variants that require minimal servicing, include components that can be exchanged easily, and use components with similar life expectancies (reliability).

A technical solution should require, in principle, as few preventive measures as possible. The means are using components of almost identical life, reliability and safe. The chosen solution should thus incorporate features that make maintenance unnecessary or reduce it substantially. Only when such features cannot be fulfilled or are too costly, should service and inspection measures be introduced.

Service measures usually refer to refilling, lubricating, conserving and cleaning. Examples are easy access, non-tiring procedures and clear instructions.

Inspection measures can be reduced to a minimum when the technical solution itself embodies direct safety techniques and thus promises high reliability.

Technical measures can reduce the service and inspection effort and include:

- Choose self balancing and self-adjusting solutions;
- Adopt a simple and with few components solution;
- Use standard solutions;
- Easy access to components;
- Provide for easy disassembly;
- Adopt modular solutions;
- Use few and similar service and inspection tools.

Maintenance should be part of an overall concept. Maintenance procedures must be compatible with functional and operational constrains of the technical system, and must be included in the overall cost along with the purchase and operating costs.

5. Conclusions

In the process of product assessment, designers should evaluate the environmental impact for every stage of the product life cycle. For some products, the usage stage can have no environmental impact, but for others, the impact might have the greatest weight.

In case of products presenting the main environmental impact during the use stage, designers must include some new specific constrains regarding product use and maintain.

The maintaining procedures and repairs performed to the product, contribute to the extension of the useful life of the product. This will lead also to an improved environmental impact during product use.

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