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EcoDesign: case of a mini compressor re-design

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Abstract

This article demonstrates the application of EcoDesign techniques in the re-design of a fish tank air compressor. This application aims the reduction of components, the minimization of raw materials and the manufacture processes and tends as main focus the minimization of environmental impact in the development of new products. This air compressor was awarded the first prize in the Product Project category in the ECODESIGN Award – FIESP/CIESP 2004.

Keywords: EcoDesign; Design; Junction elements

1. Introduction

Environmental concern and responsibility with natural systems have grown largely in all fields of society over the past years. Many countries have adopted stricter environmental legislation, taxes and penalties in order to control the whole productive system. The level of information provided nowadays has turned citizens more aware and receptive to environmentally friendly products. These pressures over the society and governments led companies to reevaluate their processes and the way their products are developed. According to Manzini et al. [1], it is possible to say that the designer has always been motivated by the search for new challenges. Within this new context, sustainable development demands a new attitude from designers: just knowing materials and processes is no longer the sufficient condition in this new paradigm; it is also necessary to approach environmental issues such as new ways to rethink, refund, reduce, reuse, or recycle a product. According to Boothroyd et al. [2], it can be appointed that the new challenge is the issue of junction elements (fixations systems among components). One of the main characteristics required by the project is to obtain a product that is easy to disassemble at the end of its shelf life. So, the aim of this work is to demonstrate the viability of a re-project of an existing product, focusing on minimization of environmental impact during its lifecycle applying the techniques of EcoDesign and helping designers to understand this new concept and its application during the whole designing process.

2. EcoDesign

The EcoDesign during product development process attempts to include the environmental variables from the conception and places environment at the same level of importance as efficiency, aesthetics, costs, ergonomics, and functionality [3]. Any business strategy employing the EcoDesign techniques in its development will have a competitive differential, promoting the integration among various sectors in the industry throughout the productive chain. This technique should be supported by the high management discussing and by the introduction

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Fig. 1. Environmental variables in briefing phase.

of a wider vision of the subject incorporating the environmental factor as one of the important values for the company.

Design and Engineering hold one of the major challenges in the search of evaluation and analysis criteria for further development of ecologically friendly products. When well managed, this decision will determine the success of the enterprise by changing existing products – with generating characteristics of great environmental impact – into EcoProducts, minimizing, therefore, environmental harms. According to Amaral de Souza [4], EcoDesign is a holistic view in that, starting from the moment we know the environmental problems and its causes, we begin to influence the conception, the materials selection, the production, the use, the reuse, the recycling and the final disposition of industrial products.

These stages aim of aggregating basic concepts that will ensure the implementation of the EcoDesign as a technique for product development, incorporating the principles of the productive chain, from raw material selection to the end of shelf life, proving the environmental responsibility of the manufacturer.

3. EcoDesign methodology for development of sustainable products

The environmental variables can be inserted, according Platcheck et al. [6], in the methodology for the development of industrial products since the definition of the problem (Fig. 1), in order to meet issues involving environmental management and sustainable development. The introduction of the environmental variables becomes fundamental for the development of new products, integrating the aspects related to the environment through the development of routines, production, use and final disposal of each product. In this manner, the designer should seek solutions in order to minimize waste generation of any kind during the many stages of product development, and thus, facilitating the recycling process and/or reducing the consequences of final disposal of the product.

For the target goals and imposed restrictions, one should consider the environmental factor, either for the reduction of the impact caused by extraction and transformation of raw materials or in the productive process, utilization, and final disposal of products in the environment. For the state-of-art survey, however, environmental issues are applied in all substages. In the productive process of existing similar products, we should consider not only manufacturing and transformation processes, assembly line, administrative and technical aspects of manufacturing but also water and energy consumption, the source of raw materials, the kind of generated residues and their destination. During this phase of the project, the method is restructured by the analysis of similar. Besides all structural, functional, ergonomic, aesthetic and market aspects, the analysis of similar should also include ecological aspects such as analysis of lifecycles, assembly and disassembly aspects, package, transportation, recycling after disposal, generation of wastes during shelf life, manufacturing processes, raw material and its sources, generated/spent energy both in the manufacturing and in the usage of the product. Fig. 2 describes these stages.

Fig. 3 shows that it is exactly during the projectation phase that the variables of EcoDesign are applied. When setting the projectual parameters we must consider that the *Waves of Eco-Design* [6] is fundamental for a sustainable development. We must regard the selection of materials with little environmental impact, the transportation system and packaging, the energy consumption, the consumption of water and auxiliary materials for both production and use of final product, the lifecycle, the reuse, and the remanufacturing and recycling of the whole product or part of it.

For the technical detailing of parts and components it is important to observe the variables of production optimization in order to reduce energy consumption, reuse sub-products and, consequently, minimize waste generation. The guidelines and rules of Design for Assembly (DfA) must also be considered, since they aim at reducing the amount and diversity of components and processes, optimizing handling, and, most of all, making the assembly of parts an easier task. As for the ergonomics recommendations, one must take into account not only the end user but also the ‘‘shop floor’’ user who acts on the production process. The Design for Assembly (DfA), Design for Disassembly (DfD), and Design for Maintenance (DfM) approaches must be considered in order to facilitate the reuse of parts and components.

During the whole process – from projectation to prototype validation – one should employ the Simultaneous Engineering, also known as Concurrent Engineering that consists of a temporal execution of various stages of activities in *parallel*, as opposing to the conventional way (sequential). Simultaneous Engineering leads to the reduction of the total development time of a product. Tasks are run in parallel allowing the effective anticipation of problems that otherwise – in the Sequential Engineering – would be detected rather late. Concurrent Engineering techniques are used to reduce loss of time and costs in product development.

This holistic view proposed by the EcoDesign should include three balanced aspects: economic viability, environment maintenance, and social responsibility. When given the same value, these aspects will ensure sustainable development, which leads to the Design for Environment (DfE) approach. When environmental problems and their causes are recognized, one is able to

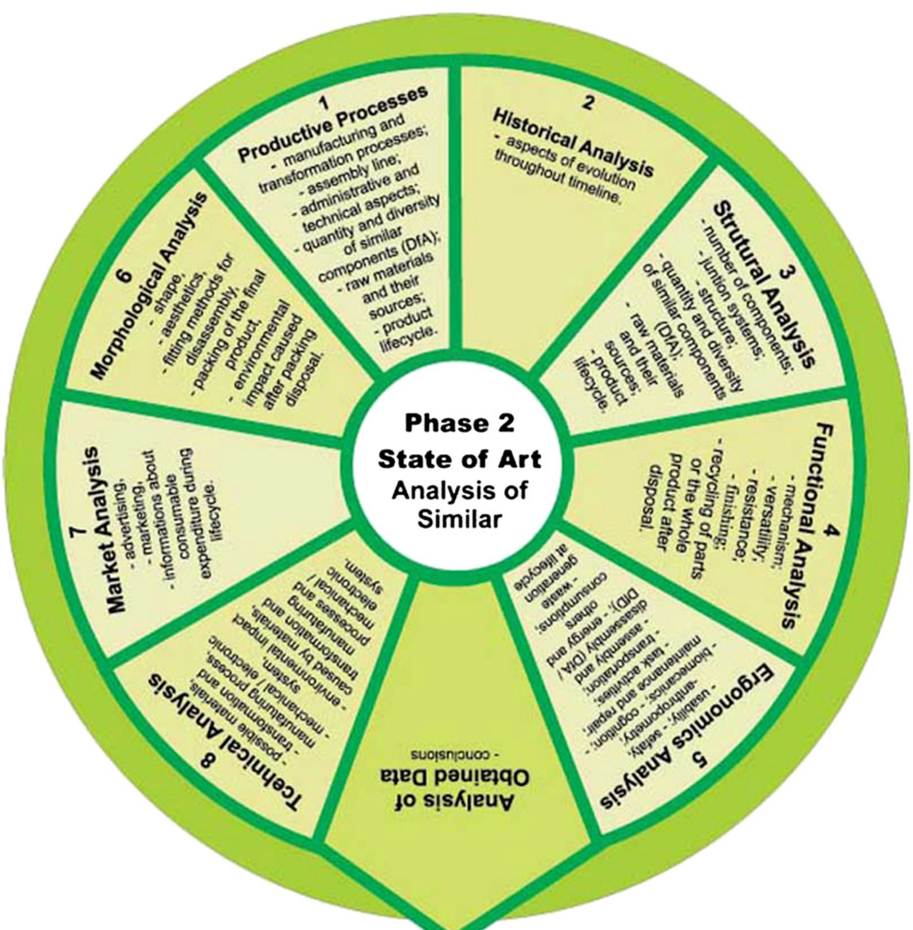

Fig. 2. Environmental variables in state-of-art phase.

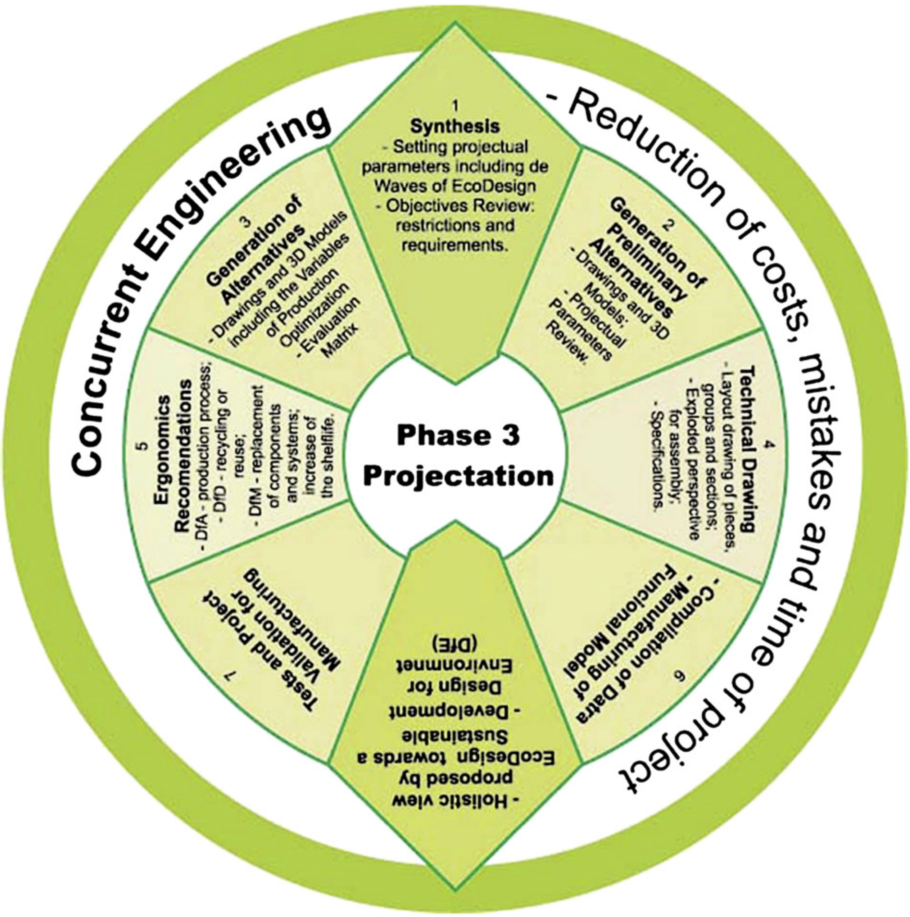

Fig. 3. Environmental variables in projectation phase.

interfere with the conception, material selection, manufacturing, use, reuse, recycling, and final disposal of a product, following what is technologically possible and ecologically necessary.

Professionals of design as well as the top management should be the main conductors of this change in course and paradigm shift from natural resources to a more evolved and sustainable type of material extraction. This change of paradigms must occur in both production processes and final products. It cannot be restricted to law compliance, but, rather, it should take advantage of the benefits and opportunities that environmental protection is able to provide. The sponsor of companies and the increase in the production of ecologically efficient products based on the application of EcoDesign will

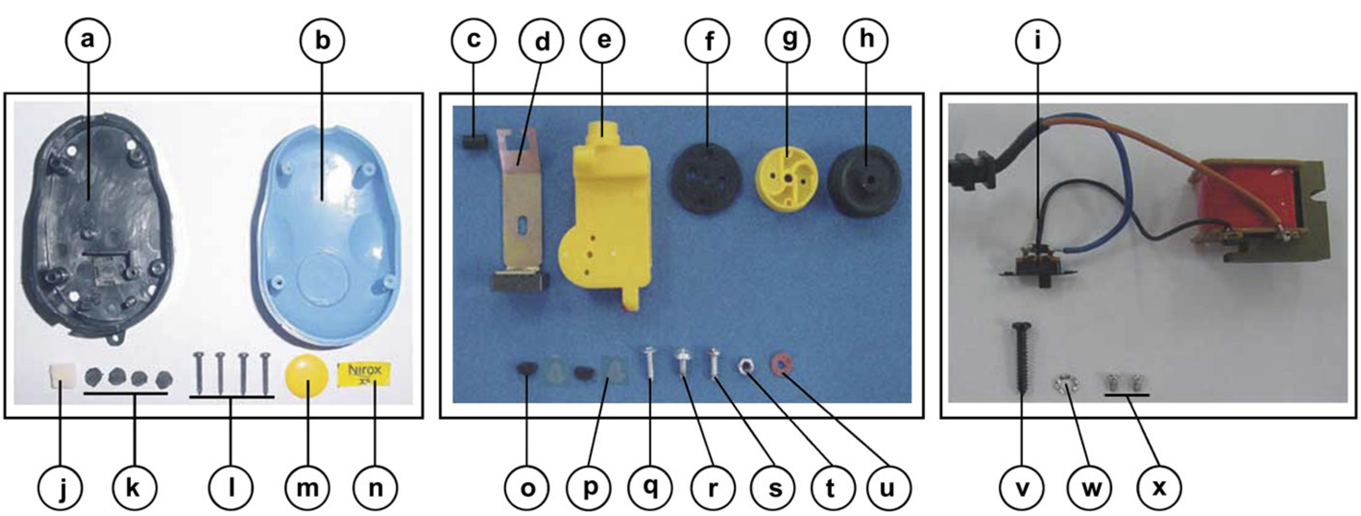

Fig. 4. Components of compressor Model A.

Table 1
Compressor Model A – Identification of components

Item	Denomination	Function	Material	Quantity
a	Lower base	Base for assembly	Thermoplastic	1
b	Upper base	Closure of the whole set	Thermoplastic	1
c	Tube	Positioning	Elastomer	1
d	Oscillating arm	Vibrator	Steel + magnet	2
e	Air collector	Air distribution	Thermoplastic	1
f	Ring	Sealing	Elastomer	1
g	Base of the valve	Body of the valve	Thermoplastic	1
h	Diaphragm	Oxygen intake	Elastomer	1
i	Controller	Key	Polymer	1
J	Filter	Oxygen filtering	Felt	1
k	Support	Support	Elastomer	4
I	Screw	Fixation	Steel	4
m	Disc	Decorative item	Thermoplastic	1
n	Adhesive tape	Product identification	Thermoplastic	1
o	Fastener	Fixation	Elastomer	2
p	Membrane	Sealing	Elastomer	2
q	Screw	Fixation	Steel	1
r	Screw	Base for assembly	Steel	1
s	Screw	Fixation	Steel	1
t	Nut	Attach item b in item j	Steel	1
u	Washer	Spacer	Composite	1
v	Screw	Fixation	Steel	1
w	Special washer	Lock	Steel	1
x	Screw	Fixation	Steel	2
Total				34

certainly bring benefits and opportunities. Within this context, the EcoDesign should be assumed as a challenge that sooner or later companies will have to face and for which they should be prepared.

4. Junction elements

Concerns and responsibilities with environmental impact have given rise to new challenges for Designers and Engineers.

Table 2
Compressor Model B – Identification of components

Item	Denomination	Function	Material	Quantity
a	Upper base	Base	Polymer + steel	2
b	Lower base	Closure of the whole set	Elastomer	1
c	Tube	Positioning	Elastomer	1
d	Oscillating arm	Vibration	Steel + magnet	2
e	Valve	Valve	Polymer	1
f	Diaphragm	Vibration	Elastomer	1
g	Selling ring	Selling	Elastomer	1
h	Washer	Electric coil fixation	Steel	1
i	Hexagonal nut	Electric coil locking	Steel	1
J	Fastener	Valve membrane fixation	Elastomer	2
k	Membrane	Sealing	Elastomer	2
1	Tube	Connection	Polymer	1
m	Hexagonal nut	Fix item b in item d	Steel	1
n	Screw	Attach item b in item d	Steel	1
o	Screw	Fixation	Steel	1
Total				19

Junction elements are largely employed in the industry for products development and have a fundamental role within this context. That happens since the greatest challenge imposed by this new environmental order. The conception of junction elements actually is able to reduce environmental impact, minimize productive process and facilitate reutilization and recycling of products. These variables tend to make disassembling easier and, therefore, more attractive for recycling centers – the main responsible for the destination and separation of a product's components.

A great difficulty for a product disassembling is observed due to junction elements, such as: glue, special screws, rivets, etc. These elements require a great deal of disassembling time, a negative characteristic considering that this fact aggregates high cost to the process and render disassembling unviable or even impossible to be performed. Kindlein et al. [5] present

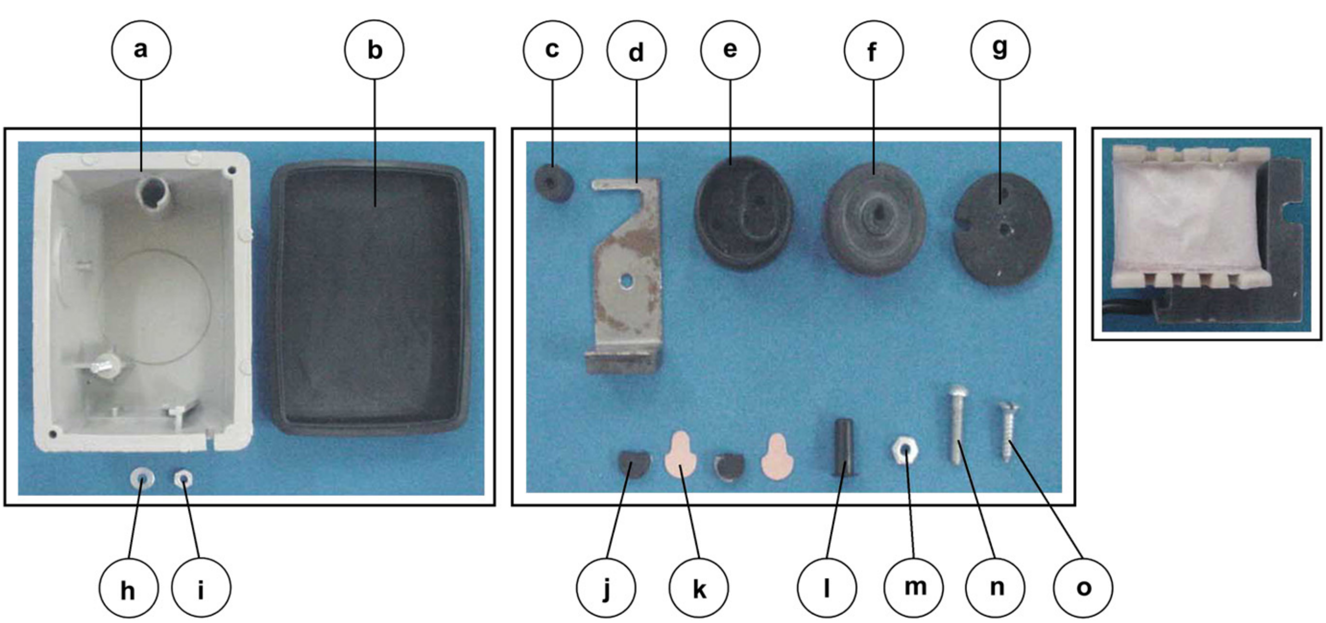

Fig. 5. Components of compressor Model B.

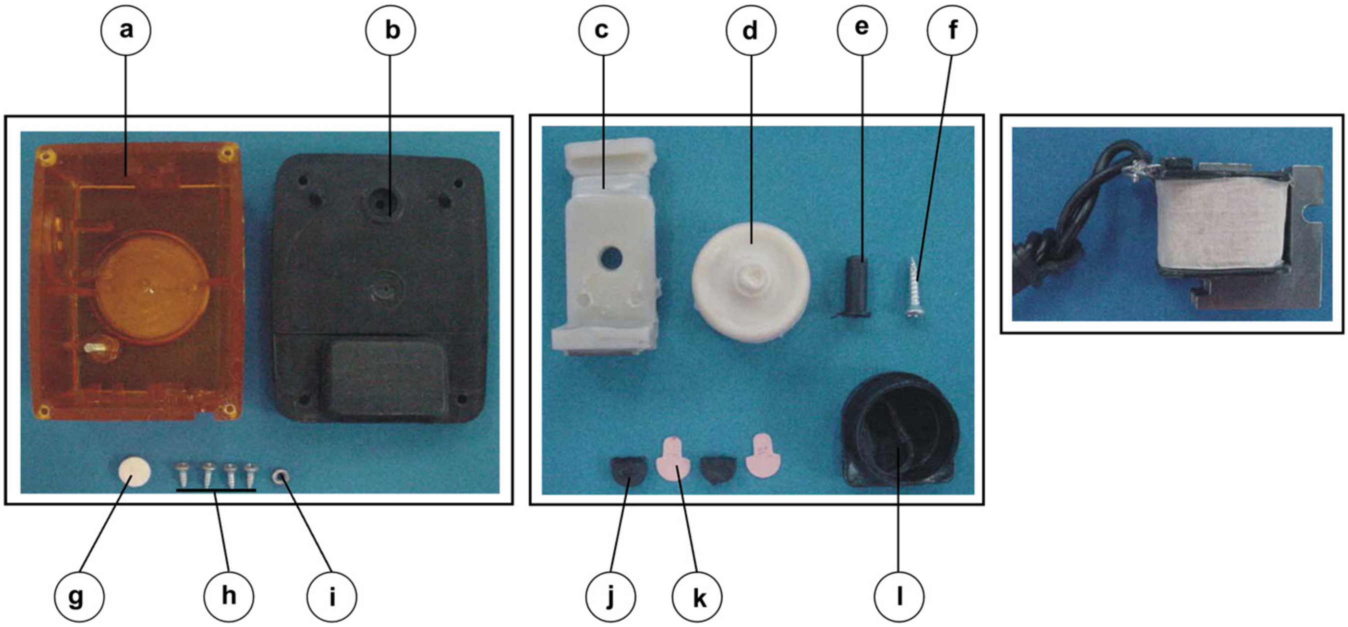

Fig. 6. Components of compressor Model C.

junction principles, sub-principles and their synonyms, explaining and describing each specific term.

By understanding junction elements and their forms, according Platcheck [6], the designer is able to employ them in the most suitable way, never forgetting to adequate this knowledge to the EcoDesign techniques for product assembling and disassembling. Applying this new kind of project to existing products requires continuous dedication. It is fundamental to consider all involved processes, its characteristics and, mainly, to know how to take advantage of that change as a positive factor and value aggregator, for both manufacturers and society, considering also the decrease of environment aggression and the raw materials extraction. When applied under the junction elements approach, the EcoDesign technique is an alternative way to achieve the redesign of products. Based on an academic case study, this article intends to demonstrate the use of the aforementioned technique.

Table 3
Compressor Model C – Identification of components

Item	Denomination	Function	Material	Quantity
a	Upper base	Base	Polymer + steel	2
b	Lower base	Closure of the whole set	Elastomer	1
c	Oscillating aim	Vibration	Steel + magnet	2
d	Diaphragm	Oxygen collection	Elastomer	1
e	Tube	Connection	Polymer	1
f	Screw	Fixation	Steel	1
g	Filter	Filter	Felt	1
h	Screw	Fix item b in item a	Steel	4
i	Hexagonal nut	Electric coil fixation	Steel	1
J	Fastener	Fix membrane of the valve	Elastomer	2
k	Membrane	Sealing	Elastomer	2
I	Base of the valve	Body of the valve	Polymer	1
Total				19

5. Case study – fish tank air compressor

The aim of this study was to evaluate the mechanical construction of 4 (four) air compressors for fish tanks available in the market, taking into account material selection and junction elements. This work did not intend to change the compressor's functional system; its main objective was to propose viable redesigning alternatives with emphasis on component reduction, minimization of raw material, maximum utilization of compatible raw material, and reduction of manufacturing processes. It was an academic proposal demonstrating how the variables of EcoDesign could be applied to produce more environment friendly products. These purposes had no real confirmation of production, users, disassembly or recycling.

6. Study of available fish tank air compressor models

The selected air compressors were chosen based on their similarity, regardless of their brand or position in the market. We analyzed four air compressors – Model A, Model B, Model C and Model D – do not considering the electric coil that is a commercial standard.

– Study of compressor Model A

Fig. 4 presents the functional structure of Model A. Its components are identified in Table 1.

– Study of compressor Model B

Fig. 5 presents the functional structure of Model B. Its components are identified in Table 2.

– Study of compressor Model C

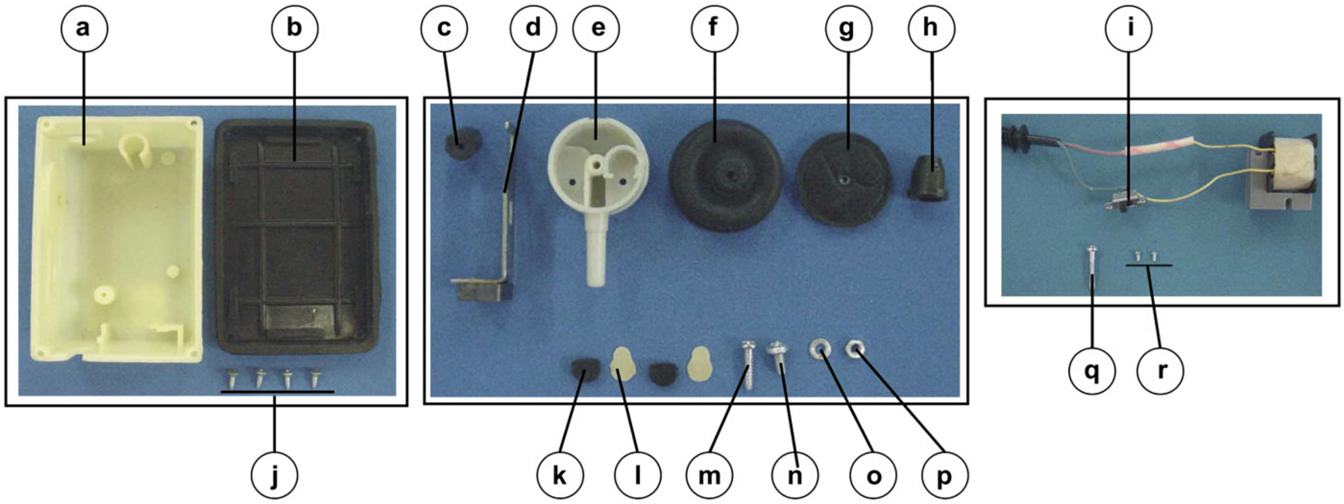

Fig. 7. Components of compressor Model D.

Fig. 6 presents the functional structure of Model C and its components are identified in Table 3.

– Study of compressor Model D

Fig. 7 presents the functional structure of Model D and its components are identified in Table 4.

7. Analysis of existing compressors

7.1. Functional re-project based on EcoDesign

Based on the data provided by the evaluation of available compressors, we began to analyze and determine the specifications of viable aspects for redesigning according to the EcoDesign variables. During this phase, two possible re-project lines were determined: one related to the structure of the product and the other concerning the analysis of materials and processes. The analysis focused on those two lines with emphasis on alterations in the following topics: reduction of components, junction elements, raw material selection, and minimization of processes while preserving characteristics and performance of air generation system. Table 5 shows a quantitative analysis of the number of parts necessary to assemble each set. This is a fundamental information in the evaluation of similar and an important aspect for possible project solutions.

Table 4
Compressor Model D – identification of components

Item	Denomination	Function	Material	Quantity
a	Upper base	Base	Polymer	1
b	Lower base	Closure of the whole set	Elastomer	1
c	Tube	Positioning	Elastomer	1
d	Oscillating arm	Vibration	Steel + magnet	2
e	Base of the valve	Body of the valve	Polymer	1
f	Diaphragm	Catcher	Elastomer	1
g	Sealing ring	Sealing	Elastomer	1
h	Guide	Positioning of tube item c	Polymer	1
i	Controller	Key	Polymer	1
j	Screw	Fix item b in item a	Steel	4
k	Fastener	Fix membrane of the valve	Elastomer	2
I	Membrane	Sealing	Elastomer	2
m	Screw	Fixation	Steel	1
n	Screw	Attach item b in item 4	Steel	1
0	Washer	Spacer	Steel	1
P	Hexagonal nut	Fix item b in item d	Steel	1
q	Screw	Fixation	Steel	1
r	Locking screw	Control key	Steel	2
Total				25

7.2. Conceptual re-project based on EcoDesign

Based on data presented in Table 5, we began to develop the conceptual redesign in order to change the conception of the product – reduction of components and maintenance of functionality, in compliance with technical, economic and environmental criteria. With the help of 3D software, a compressor model was developed as shown in Fig. 8. The model was based on the EcoDesign variables and aimed of reducing environmental impact and increasing productive and competitive differential. Then, the final product could contemplate leaner manufacturing processes.

The project including single components, which previously was based in the assembly of two or more components, enabled the reduction of items and the application of the pressure injection process to manufacture plastic items. Components 1 and 2 are responsible for the compressor's structure, positioning of internal components, protection of internal components,

Table 5
Number of components in each analyzed compressor models

Compressor model	Basic set	Air generation set	Total items
A	13	16	29
B	05	14	19
C	09	10	19
D	06	15	21

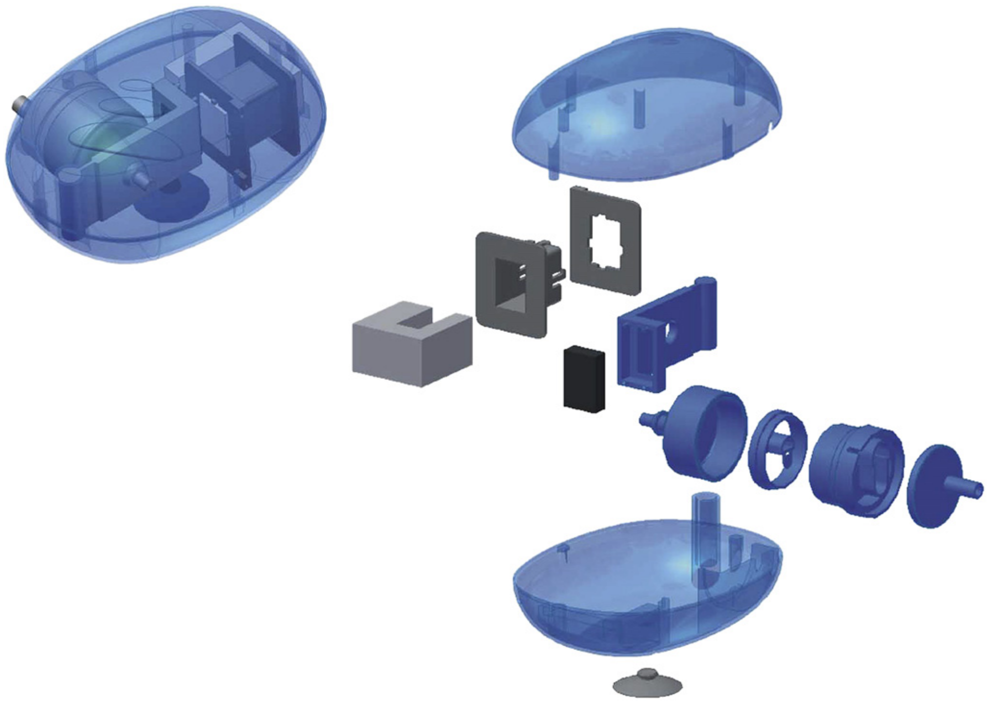

Fig. 8. Exploded view of compressor proposed by the LdSM.

and external product appearance (aesthetics). Fixation systems were employed to these components without the use of items such as screws, nuts or glue. One of the systems used for closing the lid is the so-called *Snap-fit*. This system negates the need of screws to attach two parts. Fig. 9 shows the items described in Table 6. It is worth emphasizing that the project developed by the LdSM proposed a new design for the electric coil. In the other compressors this item is critical since it involves several materials and junction elements that make disassemble a hard task to perform.

8. Analogy between available products and the new proposal

This new proposal of an air compressor for fish tank arose from the principle of raw material waste reduction and improvement of processes. It is based on the analogy and analysis of existing products available in the market and can be applied to any other product. The main concern here is the minimization of environmental impact and industrial cost demanded by manufacturing process through the utilization of compatible materials, the application of the EcoDesign technique and, most of all, the reutilization of components in order to increase lifecycle and possibilities of product recycling. Table 7 presents a quantitative analogy between available products and the result of the redesign proposed by LdSM.

9. Prototyping of air compressor developed by LdSM

After the conclusion of the 3D virtual model, the prototyping of the product was created through *SLS – Selective Laser Sintering*. With this technique it is possible to produce a physical model by using the energy released by a leaser beam to

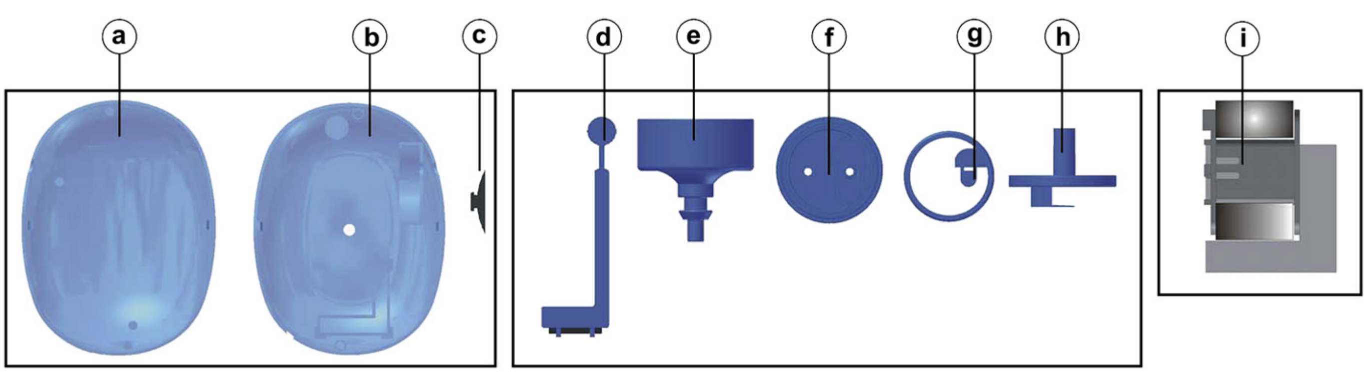

Fig. 9. Components of compressor developed by the LdSM.

Table 6
LdSM model – identification of components

Item	Denomination	Function	Material	Quantity
a	Upper base	Closing the whole set	Polymer	1
b	Lower base	Base	Polymer	1
c	Sucker	Fixation	Polymer	1
d	Oscillating arm	Vibration	Polymer + magnet	2
e	Diaphragm	Catcher	Elastomer	1
f	Base of the valve	Body of the valve	Polymer	1
g	Membrane	Sealing	Polymer	1
h	Membrane	Sealing	Polymer	1
i	Electric coil	Magnetic field	Polymer	1
Total				10

Table 7
Analogy: existing products versus the one based on EcoDesign

Compressor model	Basic set	Air generation set	Electric coil set	Total of parts	Different materials
A	13	16	01	30	06
B	05	14	01	20	04
C	09	10	01	20	05
D	06	15	01	22	04
Developed by LdSM	03	06	01	10	04

melt a heated powder. This extremely important process was chosen due to its dimensional precision and its availability at CenPRA – Renato Archer Research Center. The material employed in the compressor prototype was Polyamide. Through the prototyping technique, the analysis of design and characteristics of assembly become quite evident; therefore, it is possible to approve the product or conduct any modifications at lower costs and prior to the final productive process. Fig. 10 shows the prototype developed by LdSM. It is clear that there was a significant reduction in number of components when compared to similar products analyzed in this work.

10. Analysis of results

The quantitative analysis (Table 7) reveals that it was possible to develop or redesign a product tends as base of project information that comes to join knowledge and viable techniques of environmental adaptation. In this specific case the main focus was the development of a product with a lower number of components and leaner processes. This change in product tends to aggregate a competitive and strategic differential to the company by maintaining traditional project criteria but attributing the same value to the environmental variable as that given to other industrial strategies such as profit, quality, functionality, aesthetics, ergonomics and the image of the company in society.

11. Conclusion

Environmental pressures from both society and government have led companies to apply environmental strategies for the development of products. The EcoDesign technique is not only fundamental for process enhancement and development of components but also enables designers to project or redesign products taking into account environmental issues. Through this technique, useful and efficient junction elements receive a touch of innovation. Conventional systems such as screws, nuts, glue, etc., as well as disassembly tools like screwdrivers or pliers are no longer necessary. In order to apply this technique, however, a critical analysis of each product must be carried out. Strategies and viable alternatives must be set so as to avoid unequivocal decisions that might inhibit this practice of environmental responsibility with sustainable development. This article demonstrates a possible way of balancing sustainable development and economic interests involved in the development of a product. This work is the foundation for future works in both academic field and industrial world. However, this environmental sustainability of products and current processes will only be achieved with greater commitment in the development of products and the use of redesign with focus on the EcoDesign technique. This method can be used to analyze any type of product.

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Fig. 10. Prototyped model-air compressor developed by LdSM.

References

[1] Manzini E, et al. O Desenvolvimento de Produtos Sustentáveis. São Paulo: Editora Edusp; 2002.

[2] Boothroyd G, et al. Design for assembly and disassembly. Santa Catarina; 1992.

[3] Peneda C, et al. Ecodesign no Desenvolvimento dos Produtos. INETI–(Instituto Nacional de Engenharia e Tecnologia Industrial), ITA (Instituto de Tecnologias Ambientais); 1995.

[4] Amaral de Souza P. Inovação Sustentável: O Ecodesign Aplicado ao Projeto de Novos Produtos. Monografia. Porto Alegre: UFRGS/NdSM/UCS; 2001.

[5] Kindlein Jr W, et al. Princípios Básicos de Junção Utilizados em Sistemas e Subsistemas de Produtos Industriais e sua Importância no Desenvolvimento Sustentável. In: ANPPAS - Associação Nacional de Pós-Graduação e Pesquisa em Ambiente e Sociedade. Campinas SP: APPAS; 07 a 08 de nov. 2002.

[6] Platcheck ER, et al. Methodology of EcoDesign for the development of more sustainable electro-electronic equipments. Journal of Cleaner Production. January 2008;16(1):75–86.