UTILIZATION OF THE INNOVATIVE METHODS IN THE REDESIGN PROCESS OF A PRODUCT

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ABSTRACT
The failures in the products design diminish its market competitiveness. In these situations it is necessary to taken into account the corrective actions. The improvements to the product must eliminate the failures without raising up the costs for product redesign and production adjustment beyond the critical limit of 20% from the initial development costs.
This paper presents a novel methodology to approach product redesign for keeping the final result in the limits of economic competitiveness. It is based on advanced tools of competitive engineering (Functional Analysis, Failure Mode and Effects Analysis - FMEA, SQUIZ) and in order to reveal the value incorporated within product, as well as to solve innovatively various divergences imposed by the product redesign process.

KEYWORDS
product design, functional analysis, FMEA, SQUIZ

INTRODUCTION

The design process of a product involves a number of activities by one or more project teams. This process is often very complex due to the variety of information and knowledge involved, but also dynamic because of the evolving nature of the product during that process. The product is passing from the functional space to the structural space, from a list of functions to a set of interrelated components to perform the functions that must respond the product to a certain level of the quality and cost.
Presently, due to globalization, in order to remain competitive in the market, companies are forced to reconsider the design of their products. Design offices have as their objectives the reducing the time to market for a new product, the reducing the costs and customization of the products. Another important aspect is the involvement of multidisciplinary teams to the design a product and the geographical distribution (in cities or even different countries) to increase the skills and creativity. Not least, parallel approach of the tasks is becoming more and more frequent as a method of reducing the duration of the design. Using modern methods of design usually well solved problems, but introduces a number of risks: nonconformities of design, budget overruns, failure duration, etc. Thus, to prevent or correct bad situations can take a number of activities. They can be integrated into the design process or are activities that take place downstream, for the product redesign.
This paper presents an approach to redesign a product to increase market competitiveness. This approach is based on the methods like Functional Analysis, Failure Modes and Effects Analysis and SQUIZ.

IMPORTANCE OF THE DESIGN

ECONOMIC IMPORTANCE (COSTS, DEADLINES ...)

Since the early 80s, the strategy of competition among firms has changed. Competitive companies are those that are able to quickly transform new ideas into new products or develop their products by controlling their design process. Perrin (1) reported the results of a survey of the 90 companies from U.S., European and Japanese objectives. Seven objectives of product innovation have been previously identified. The companies were therefore asked to indicate those they affect the most resources. The survey results are summarized in the table below.

Table 1 - The results of a survey of U.S. companies, European and Japanese (Perrin)

Objectives	% of responses
Put the new product to market on time	76 %
Improve the attractiveness of new products	73 %
Develop new products faster	68 %
Develop products that are easier to produce, use and maintain	61 %
Reduce the costs of new product development	47 %
Reduce the payback period for new products	47 %
Increase the number of new products developed	44 %

IMPORTANCE OF THE DURATION OF STUDY DESIGN

The shortening of the “time to market” is increasingly a strategic variable for firms. Indeed, it frees up margins. For example, Perrin reported that the European market the car radio, the first manufacturer who announces an innovation in a product can do to pay 20% more expensive than a competitor who would introduce his own a year later. Reinertsen (2) studied the development program of a laser printer. It assessed the impact of various factors on the benefits accrued for this product. He found a six-month delay in the design and product development is the factor that has the greatest impact on expected profits with a loss of 31.5%. Exceeded 30% of the development budget is the factor with the least impact with a loss of 2.3% of the profits.

INFLUENCE OF DESIGN ON PRODUCTION COSTS

Many studies on the costs of production have shown that its costs are largely determined during the design phase of products. Perrin (1) proposes, in the figure below, an average trend of the costs incurred throughout the different phases of the life cycle of a product subject to mass production. It also represents the actual expenditure during these phases. The result is a very important result: the design activities account for only 5% of the total cost of a product when they freeze 75% of the total cost, figure 1.

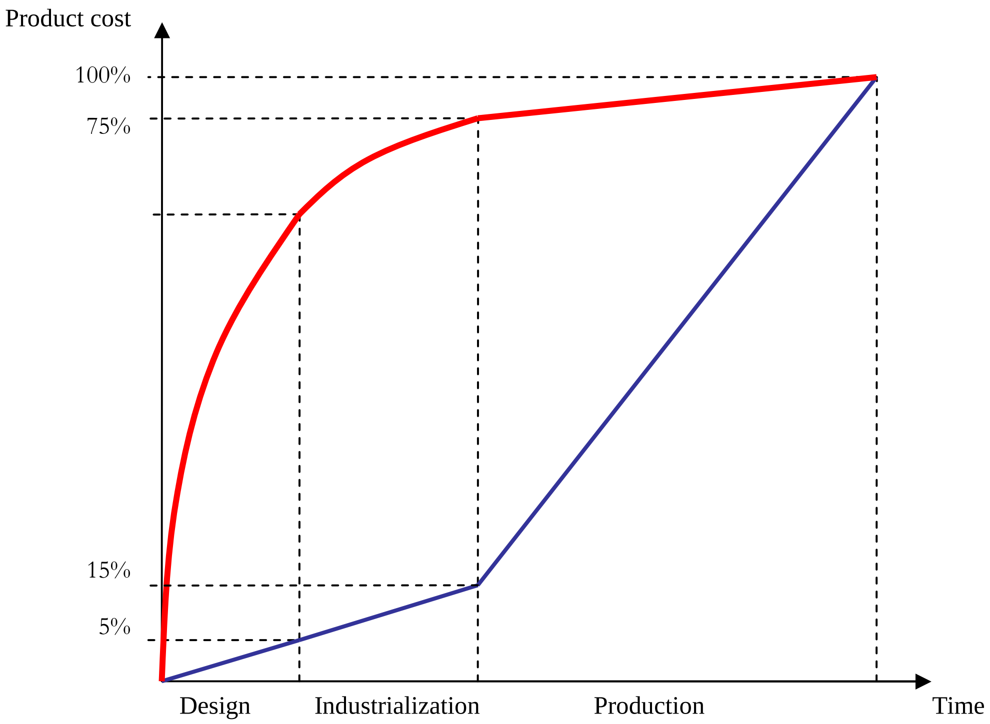


Figure 1. Design and cost of the product

Two other information is to stress on the critical role of design activities. It was during the early stages of design and we have more possibilities to change the design choices and it is during these early stages that the modification costs are lowest, figure 2.

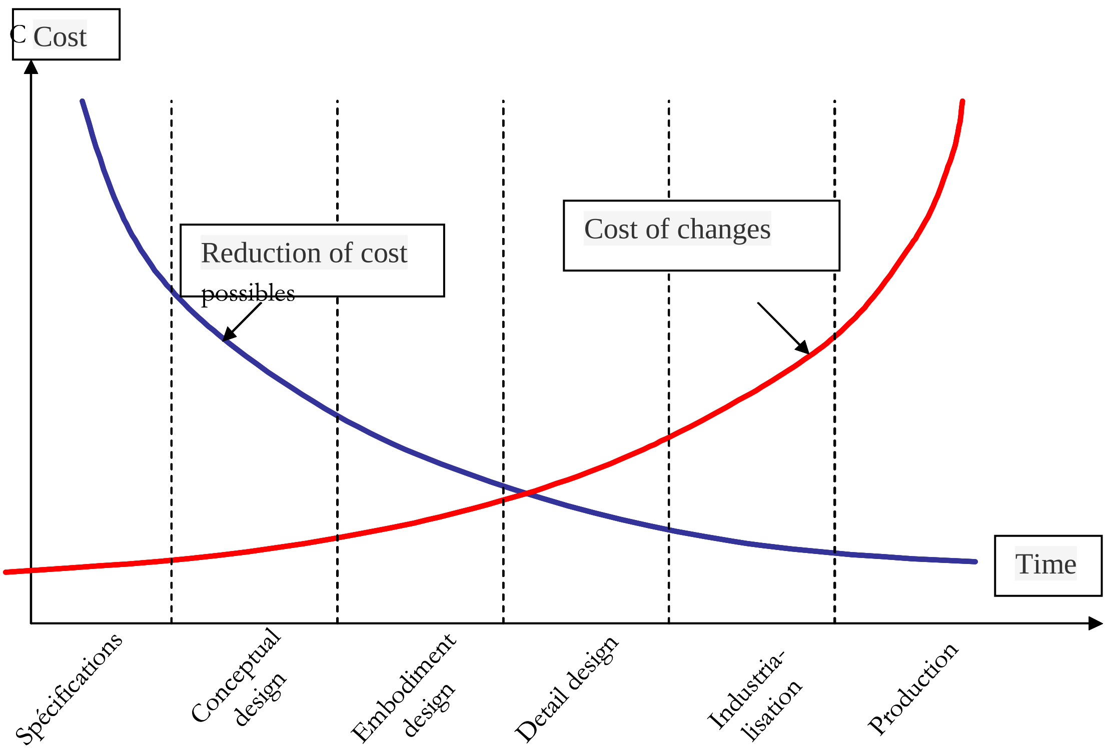


Figure 2. Influence the design phases of the possibility of costs reducing

This curve shows the importance of the early design phases. If one spends more time during these phases to better study the different design solutions with the various life cycle of the product, we certainly spend more effort but then the cost of the product and time-the market will be reduced.

METHODS USED IN INNOVATIVE DESIGN OF PRODUCTS

In the last years researchers have found concerns regarding the establishment of methods and tools to analyze and eliminate defects in early design stage, not in production or later. The results of these researches have led to the development of new methods and tools of quality with application in products design. Each solves certain issues concerning the product design. These methods are: Functional Analysis, Value Analysis (VA), Failure Modes and Effects Analysis (FMEA), Quality Function Deployment, (QFD), SQUIZ, figure 3. Value Analysis consists in studying the relationships between functions and performances on one hand, and the cost of the product on the other; the analysis, when referred to the product, determines an analysis of its parts and sub-assemblies. It is also known as Functional Cost Analysis. QFD is a method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process. All these methods can be applied to existing products to improve their quality and to design of new products.

FUNCTIONAL ANALYSIS

Functional Analysis is an approach whose goal is to express the need in terms of services expected functions and, ultimately, in terms of solutions. According to the AFNOR X50-150 standard: “Functional Analysis is an action which consists of searching, set in order, characterization, hierarchy and/or set a value (quantifying) for the functions” (3).

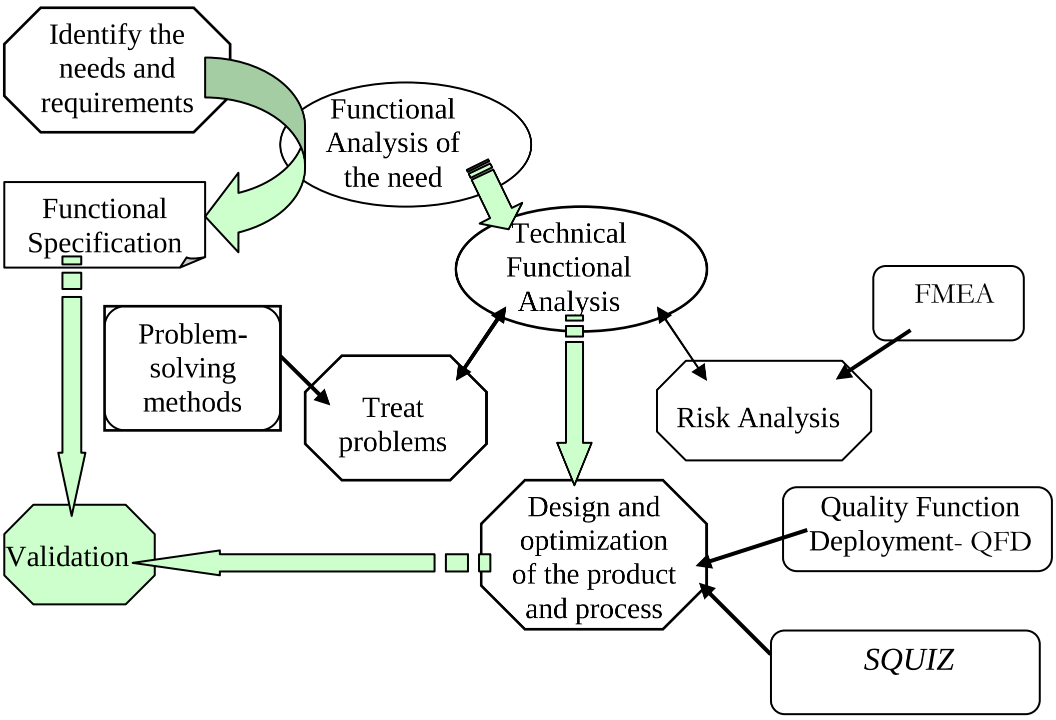


Figure 3. Functional Analysis and associated method used in the design of product

Functional Analysis can be seen as a bridge between the needs expressed by the customers and the functions that have to render the products. Through these features, Functional Analysis is essentially a way to conduct to the obtaining of the products' quality. Functional Analysis has two possibilities to be unfolded: External Functional Analysis and Internal Functional Analysis.
The method of Functional Analysis, as was made by Miles, proposes a simple principle: to establish, first, functions that must fulfill a product and then to search the product to carry out these functions. In this way a solution cannot be prosecuted or cannot be found without being reported to the functions that ensure the need to be done. The objectivity reasoning in Functional Analysis is time of fact that the solutions don't are compared between them, they are analyzed in relation to the functions fulfilled. External Functional Analysis assumes the following steps (3):
a. Identification the studied product and the life phase of it (definition of the subject);
b. Inventory of environmental elements of use. The external environment consists of the elements related with the product.
c. Establish and formalization of functions. The next step is to describe the elements of the product's environment. In this stage the functional analysis aimed at the formulation of functions, describe them with the optimum behavior of the product and its terms of usability. There are two kinds of functions; the principal functions (FP) which are at least two different environments that interact by the means of product, and the constraint functions (FC) which are generated by only one environment and that the product has to respect absolutely.
d. Control the validity of the functions;
e. Characterization and hierarchy of functions;
The result of the External Functional Analysis is the Functional Specification.

FAILURE MODE AND EFFECTS ANALYSIS (FMEA)

FMEA is a design and analysis technique that and is concerned with identifying the ways in which a product can fail and the effects of such failures. It also used to provide alternative solutions to prevent failures. FMEA should be performed both on the product and on the manufacturing process.
The principal steps of a FMEA application are described in figure 4. The starting point is the identification of the functions. After the functions were established, the next step consists in the identification of failure modes and their effects, their severity being ranked on a scale from 1 to 3. Following identifying possible causes of failure and analysing their potential consequences, it is necessary to calculate the likelihood of failure occurrence, once again on a scale from 1 to 3.

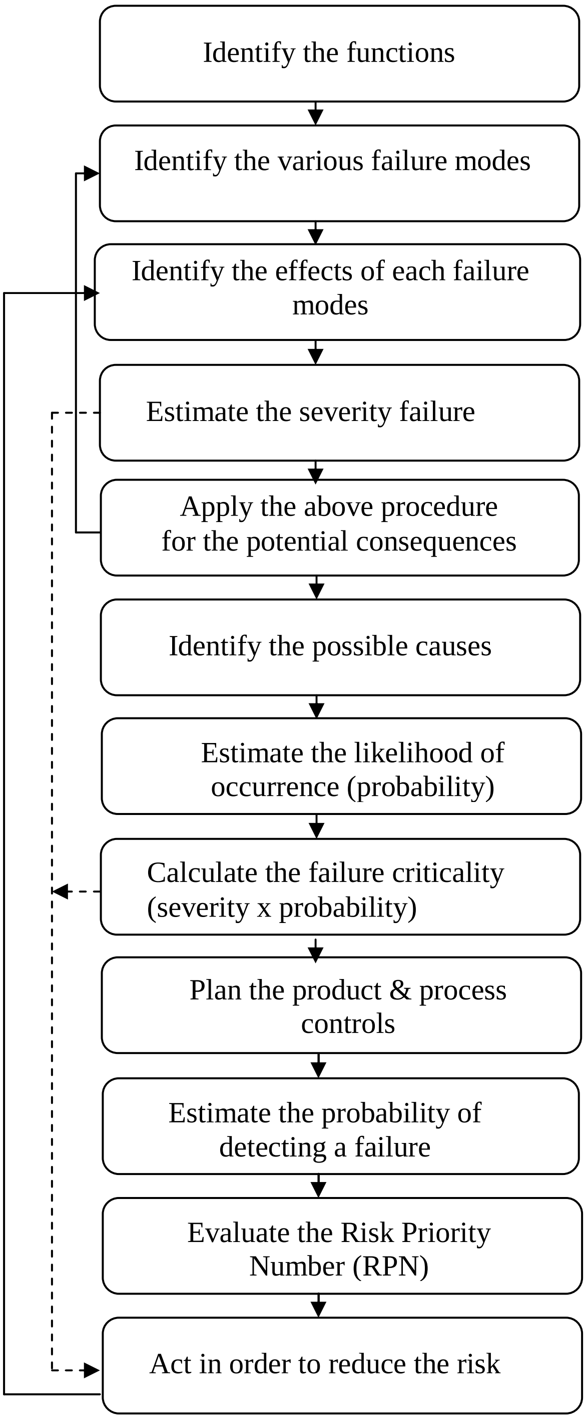


Figure 4. The Failure Mode and Effect Analysis (FMEA) methodology

When its criticality, namely the severity of failure multiplied by the likelihood of its occurrence, has been determined, it is time to define the tests to be carried out both on the product and on the process. There are three types of test: (a) type 1, to avoid the occurrence of a failure cause or mode, thus reducing the likelihood of failures, (b) type 2, to discover the cause of failure and define corrective actions, (c) type 3, to reveal failure modes before the product reaches the customer.
It is then necessary to estimate the probability of detecting a fault; the values, in this case, range from 1 (the test will nearly certainly reveal the potential cause of the failure or the

consequent failure mode) to 3 (the test will probably fail to reveal the potential cause of failure and the consequent failure mode, or the test is not carried out).
The last step is to calculate the Risk Priority Number (RPN), which is equal to the severity of failure multiplied by the probability of occurrence and the probability of interception, namely the possibility of identifying the cause of failure. This Risk Priority Number helps the work team to identify the products that need the priority actions for improvement (4).

SQUIZ

The Squiz is a procedure designed to optimize the product, it consists of a matrix which compares the features of service, technology or components of this product with themselves. This matrix considers for each element its possible substitution by another element of the product or its removal. This therefore reduces the number of elements that characterize the product (which induces a simplification of it), and it is also a source of technical innovations, to the extent that, despite the fact that most of these substitutions are absurd, it helps to consider certain that we would not have thought so obvious, but which may prove interesting.

THE IMPORTANCE OF EXPERIMENTS IN DESIGN

The design experiments are carried out to simulate a real process. The simulation of design process is a means used by the research laboratories with the aim of obtaining information regarding their behavior and the variation of their parameters (5).

EXPERIMENTAL ENVIRONMENT
FUNCTIONAL ANALYSIS OF THE PRODUCT

The product analyzed in this paper is a “vacuum cleaner”, Figure 5.

Figure 5. The product “vacuum cleaner”

To establish, for redesign the product, its links with various environmental elements, is carried out the external functional analysis of its. The analysis highlights the functions of product and directs the design team to the choice of appropriate solutions. Thus, the product architecture will contain elements that respond to the established functions. The functions are presented in the Table 2.

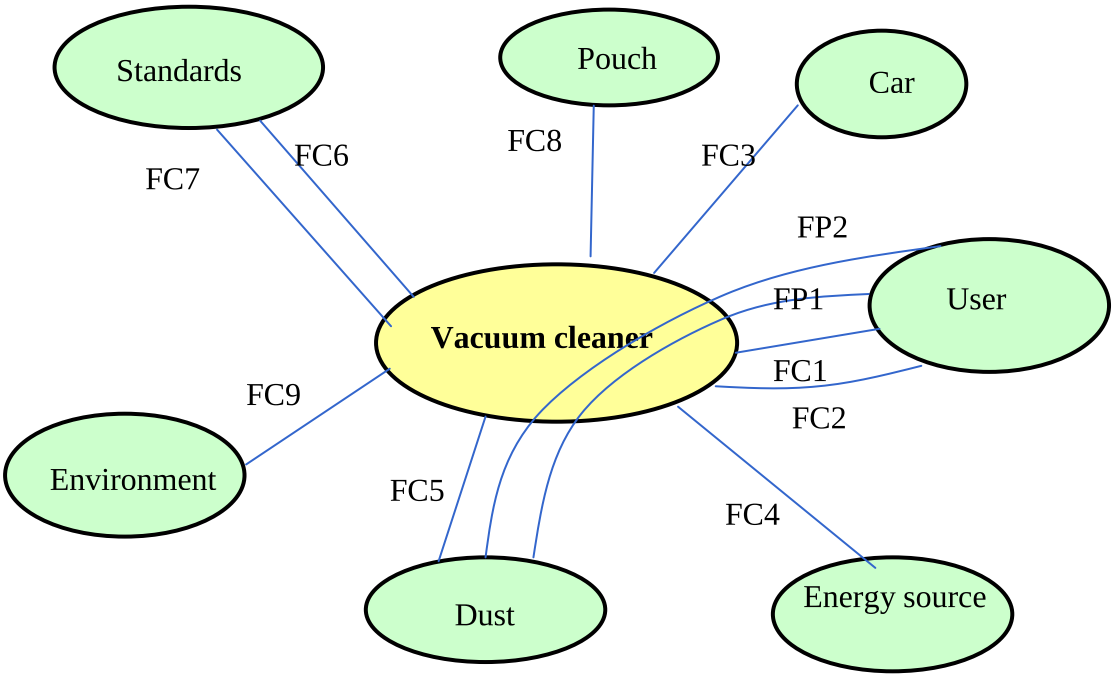


Figure 6. The environments and the service functions of the product "vacuum cleaner"

Table 2. The product's functions

Principal functions	**Constraints functions**
FP1 – To allow the user the removing of the dust FP2 – To allow the user the storing of the dust	FC1 – To be easily to use FC2 – To be easily to maintain FC3- To be easily to transported (shape, size, weight) FC4 – To be powered by a certain type of energy source FC5- To be able to remove particles with different sizes FC6 – To be silently FC7 – To present reliability FC8 – To adapt to a type of pouch FC9 – To be environment friendly

SQUIZ SERVICE FUNCTIONS

To the consolidation of the functions is carried out the SQUIZ matrix of the service functions, figure 7.

	FP1	FP2	FC1	FC2	FC3	FC4	FC5	FC6	FC7	FC8	FC9
FP1											
FP2											1
FC1									2		3
FC2									4		
FC3											
FC4											
FC5											
FC6											
FC7											
FC8											
FC9											

Figure 7. SQUIZ matrix of the service functions

1- If the vacuum cleaner can store the dust, he is friendly with the environment;
2- If vacuum cleaner is easy to use, it is safe;
3- If vacuum cleaner is easy to use, he is friendly with the environment;
4- If vacuum cleaner is easy to maintain, it is safe a long-term.

SQUIZ COMPONENTS

The SQUIZ matrix of the components helps the designers to combine multiple components, or to integrate into a main component the more secondary components, figure 8.

	electric motor	interchangeable heads	handle	tube	cable	dimmer	bag	filter	battery
electric motor								1	
interchangeable heads									
handle						2			
tube									
cable									3
dimmer									
bag								4	
filter									
battery									

Figure 8. SQUIZ matrix of the components

1- We can directly integrate the dust filter on the engine;
2- We can put the dimmer on the handle to be more ergonomic;
3- We can replace the power wire from a battery (for more accessibility);
4- We can integrate the filter on the bag (a special filter).

FAILURE MODES AND EFFECTS ANALYSIS

The analysis results are presented in the FMEA grille, table 3.
After the analysis carried out, it was found that is desirable the “vacuum cleaner” to provide more accessibility. This problem can be solved by providing the “vacuum cleaner” with cordless. To know the undesirable effects caused by this new component of the product, a new FMEA analysis of the function carried out by this component was made. Thus, the Risk Priority Number has declined much from 27 of 9 value, table 4.

Table 3. Initial FMEA grille

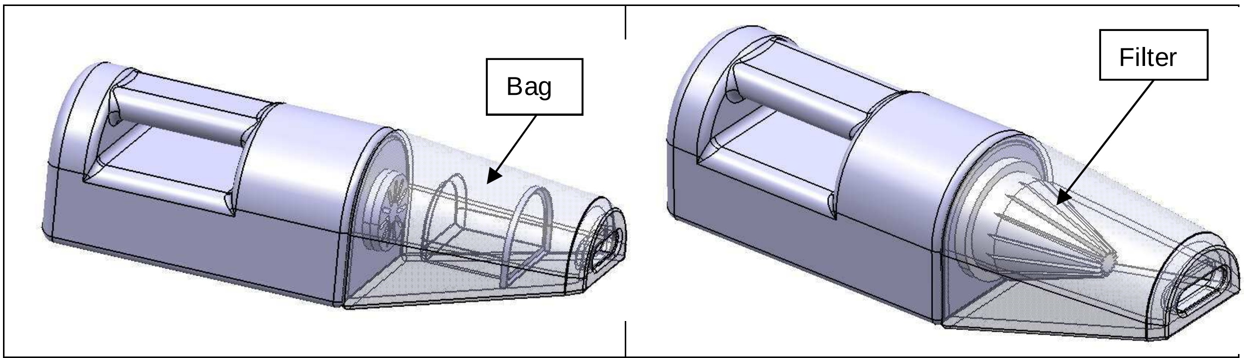
Functions	Parts	Failure mode	Causes	Effect	S	O	D	RPN	Corrective actions
FP1 – To allow the user the removing of the dust	Tube and heads	Without aspiration	Tube clogged	Does not satisfy the service function	3	3	1	9	Tests for tube
			Manufacturing or design error of the tube or head		3	3	3	27	Tests
		Insufficient aspiration	Manufacturing or design error	Partially satisfy the service function	1	3	3	9	
			Partially clogged tube		1	1	2	2	Check tube
			Improper use		1	1	3	3	User manual
FP2 – To allow the user the storing of the dust	Bag	Without aspiration	Manufacturing or design error	Does not satisfy the service function	3	3	1	9	Correlation with the specifications
		Disturbed aspiration		Partially satisfy the service function	2	3	3	18	
			Bag full		1	1	1	1	User manual
			Inadequately installed bag or other bag use		1	2	3	6	
FC4 – To be powered by a certain type of energy source	Plug, cable, connec-tors	Not working	Cable and connectors are not in contact	Does not satisfy the function	3	3	1	9	Control
			The cable is broken		3	3	1	9	Control and appropriate cable
		Malfunctions	Improper connection	Intermittent functioning	2	2	3	12	Correct sizing for the connectors

Table 3. Final FMEA grille

Functions	Parts	Failure mode	Causes	Effect	S	O	D	RPN	Corrective actions
FC4 – To be powered by a certain type of energy source	Battery	Not working	Battery damaged or improper connection	Does not satisfy the function	3	3	1	9	Battery control or connectors control
		Intermittent	Shock, vibration or improper connection	Partially satisfy the function	2	2	1	4	Redesign
		Quick discharge	Battery obsolete or improper connection		2	1	2	4	Checking the battery or the connectors
		Limited capacity	Battery obsolete or improper use		1	1	2	2	Correct charge

For the solution with bag there are some problems: sealing (the settlement of bag requires attention from the user), there is risk to sit tight after a period of time because of loss of its

geometry. After the SQUIZ analysis, it was found that we can integrate the bag into a special filter and the filter can be placed directly on the motor.
It is proposed a new solution; the bag was replaced with a filter attached to the crankcase. During the aspiration, the filter is self-fixation, increasing the sealing.



before | after

Figure 9. The solution for the function "…storing the dust".

CONCLUSIONS

Using innovative design methods provide an important support for the designers in their actions.
This paper describes the application of AF methods, FMEA and SQUIZ, and some results of applying these methods.
It is highlighted using AF in the early stages of product design to give designers a complete and accurate vision of the context in which the product exist and on its functioning.
FMEA and SQUIZ methods, guides the designers to choice the innovative solutions, offering competitive new product.

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