Interface design of a product as a potential agent for a concurrent engineering environment

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Abstract. Product design is currently a subject that involves various kinds of knowledge. In order to develop products that are successful in the market it is necessary to involve people from different areas of the production cycle, such as: marketing, assembly, processing, sales, among others, in addition to consideration of clients' wishes. To address these issues in the development of a product, a design method that uses tools based on the principles of simultaneous engineering needs to be used. Interface design of a product should consider information from the areas mentioned as well. In this way, development of a method for interface design in the initial phases of product design could be an element of effective use of Simultaneous Engineering in the design. The purpose of this paper is to describe how the development of a method for interface design can contribute to the establishment of a Simultaneous Engineering environment in the initial phases of product design. To accomplish this, it is necessary to use techniques such as DFA, DFM, and FMEA in those stages of the design.

Keywords. Interface design, Concurrent Engineering, Conceptual Design, DFA, DFM, FMEA

1 Introduction

The Concurrent Engineering (CE) is a work philosophy which objective is to enhance the product development process. This is searched by the information sharing between the different knowledge areas involved in this task.

The CE is defined like a philosophy and an environment too. How philosophy is based on the recognition of each one and your responsabilities to the product quality. Like an environment it is based on the simultaneous product development and on the processes which affect it in its lifecycle [1]. To Noble [2], CE is typically defined like the integration of the design processes: product and

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manufacture. The objective of this integration is to reduce the time and the cost of product development and to produce a product that attend to client expectations.

Kerzner [3] point that CE is an attempt to execute work in parallel. Better than those carried through sequentially - where the greater inconvenience is that the chosen conception will pass for all the stages of design without a detailed evaluation of the difficulties of manufacture (execution) of the product. This search to design 'on the right way in the first time' by means of the concurrence among the product design and its related processes.

So we can see that there are limitations on the sequential design process. Rozenfeld et al [4] point some of them:

- isolation between the product research and development and product design areas. This causes a lack of integration with the general strategy of the business. This is increased by the different languages and understands of the design problem used by those areas;
- existence of organizational and communication barriers between these areas and the remain of the company;
- little participation of the high administration in the main definitions of the goals of these areas;
- hierarquization and linearity of the information flow between the areas of the company
- little envolvement of the suppliers in the creation phases of the product;
- resistance to controls and to the accounting of costs in R&D and Product Design because these areas deal with activities of risk;
- extreme specialization of the professionals of the area;

This way the authors present a model of Design Process based on the CE principles which is formed by three phases: Informational Design, Conceptual Design and Detailed Design.

In this context, the interface design appears like a tool to effectivelly implement the CE environment. This is due to its characteristic of connect different components of product. Related to the interface design are the areas of manufacture, assembly and reliability [5]. So, the development of a methodology of interface design is a potential factor of implementation of a CE environment.

The objective of this paper is to develop a bibliographical research about the interface design to give the base to the development of a methodology of interface design in the conceptual design phase using like support tools the DFA, DFM and FMEA methods.

2 The interface design

The Conceptual Design phase (Figure 1) is considered one of the critical points in the design process [6] because it is at this point that structure and concept of the design are defined. It is estimated that up to this point about 20% of the work involved in the design is completed, and that this percentage is responsible for defining 80% of its cost [7]. This is due to the fact that the up to the Conceptual Design one is working with the abstract phase of the process, after that, one moves on to the concretization of the product. As a result of its importance, this phase has some points requiring a better definition.

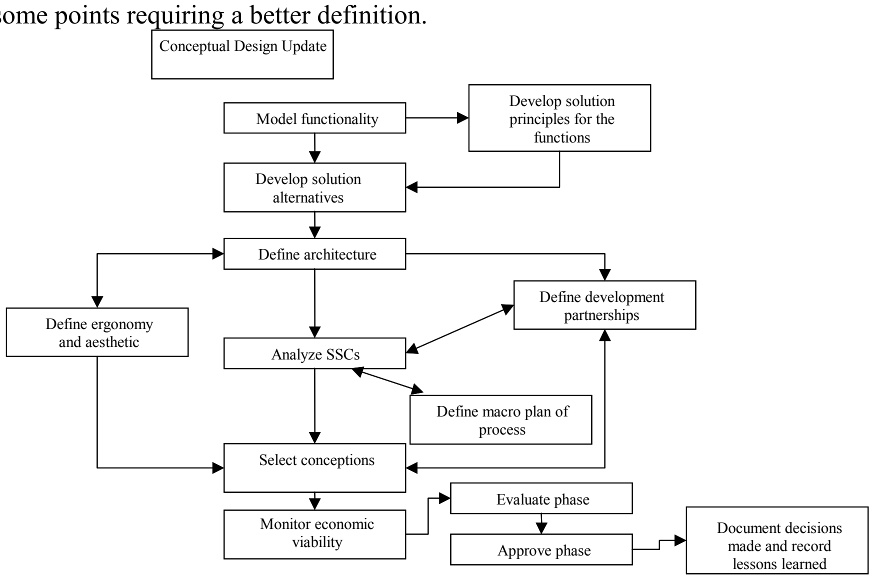

Figure 1. Conceptual Design phase [4]

Inside the conceptual design we can see some areas that still are needing of detailing like the interface design. The existing methodologies attend the interface design just in the Preliminar Design. This cause some troubles like the need of iterations due to connection fails between solution principles or the need of very complex interfaces among two principles. These troubles can cause late and increase the costs of design.

Moreover, the role of interface design is showed by Ullman [8] that consider the development of interfaces in the phase of Preliminary Design. The author point that the "functions occur in the interfaces between components". This is based on the following interface definition: "the boundary area between adjacent regions that constitutes a point where independent systems of diverse groups interact" or "the interconnection between two equipment that possesss different functions and that could not connect directly themself" [9].

The great advantage of the determination of the product interfaces is that the change of the abstraction level to the concrete level becomes less abrupt and uncertain, that is, instead of creating the solution principles directly from the structure of functions, we can reduce the possibility of problems in the posterior phases by the architecture determination of the product what includes the dfinition of its interfaces. Thus, parameters for the product development as the involved variable, flows of material energy and signal as well as the proper interfaces of the same, become more apparent for the designer.

In this direction, Ulrich and Eppinger [10] proposed a way to determine the product architecture by the mapping of interactions between functions and the possible product interfaces. However, the proposal of the authors is inserted in the Preliminary Design what indicates that for its application already exists a definite conception. Already Otto and Wood [11] describe the possibility of use of the method of Ulrich and Eppinger [10] still in the phase of Conceptual Design and, moreover, presents another proposal of generation of the architecture and determination of the possible modules that are executed by heuristical means. This proposal presents the advantage to use the specifications of design and the restrictions of the product as parameters for the development of the product architecture.

Looking for the definition of product interfaces in the literature there are some relevant proposals. Ullman [8] considers a systematics of interfaces development in the Preliminary Design in which presents some steps that go since the concern with the rocking of energy, material and information in the level of functions, passing to the most critical interfaces determination, the maintenance of the functional independence of subsystems and components and the care in separating the design in distinct components. Another proposal to interface development is made by Otto and Wood [11]. The authors point the necessity of initially to define the product architecture and, based on this, to define preliminary layouts. So, we can establish the product interfaces. However, the authors do not say as to make it.

Another work carried through in the direction to evaluate new techniques of development of concepts is of Sousa [12]. He made an analysis of the use of methods of Design for Manufacture and Assembly in the Conceptual Design. In this study the author points that the requirements of manufacture and assembly, beyond the functional requirements, are important for the evaluation of the product structures. Also he places that, for does not being made a correct evaluation of the product assembly and manufacture in the phase of Conceptual Design, there are unnecessary iterations when the design already meets in the Preliminary and Detailed phases returning to the Conceptual Design, also. These iterations finish for causing increases of costs, delays and reworks that could be prevented.

Ullman [8] and Linhares and Dias [13] places that CE must consider four basic elements: function, geometry, material and manufacturing processes. Moreover, they place that design and manufacture (including the assembly) must simultaneously be developed. Also point that the development of each part needs to be integrated to the funtions definition and refinement and its respective interfaces. Linhares and Dias [13] point too that the design must take in account two tasks in the individual conception of a part: (1) to design it like it was a product and (2) to consider that it is part of a realizable module and to take in account its interfaces. Siqueira and Forcellini [14] make the consideration that the requirements of the unions are excellent factors in the election of conceptions.

This way, we can see the role of the execution of the product interface design in the initial stages of the design process. This can to increase the knowledge of the design team about the designed product . However, its necessary to use methods and tools of support. So we will analyse some of them.

3 Support methods and tools to the interface design to the initial phases of the product development

In this topic the methods of DFA and DFM and the tool of FMEA will be boarded as auxiliary mechanisms in the product development process and especifically in the interface development in the early phases of the design process.

DFA e DFM

The methods of DFA and DFM aim to optimize the design in the phase of definition of processes and final shapes, searching lesser times and costs. These methods had been developed by Boothroyd, Dewhrust and Knight [15] and, initially, was used in set (DFMA). However, due to importance of each one of the processes and the possibility to be applied separately in agreement the case, them they had been branched in two methods: DFM and DFA. To have an idea of the relevance of such methods Boothroyd, Dewhrust and Knight [15] and Pereira and Manke [16] esteem that 50% of the manufacture costs are related to the assembly process and both represent a great parcel in the final cost of the product.

Moreover, the two methods are based on the last experience and search to expose and systemize the knowledge [17]. Thus, its role is observed as mechanisms not only of aid technician but, also, of support to the management of knowledge of the company.

However, for its application, it is necessary that there is an integrated product development environment, with processes and products engineers working in set in the early phases of design. This is another characteristic of the DFMA methods. It require the implementation of a CE environment with representants of different knowledge areas in the design team.

To Keys apud Valeri and Trabasso [18] the DFX methods can be defined as being “a set of techniques generally applied in the early phases of the integrated products development, to guarantee that the hole lifecycle will be considered in the product design”. In this definition the authors point that the DFM method is one “technic applied in design, aiming at definition of alternatives which optimize the manufacture system as a whole, identifying concepts of easy manufacturing products, help the design of these kind of products, facilitates the integration between the development of manufacture processes and the design of the product”. Therefore, Stoll apud Valeri and Trabasso [18] place a list of directives for the DFM:

- to minimize the number of parts;
- to develop modular designs;
- to minimize the variations of parts;
- to design multi-functional parts;
- to design parts for multipurpose;
- to facilitate the manufacture;
- to prevent the separate fixing use;
- to diminish the assembly directions;
- to maximize the of the assemblies;

- to minimize the handle;
- to evaluate the assembly methods;
- to eliminate or to simplify the adjustments.

Relative to DFA Lee and Hahn apud Valeri and Trabasso [18] define it as "a group of design techniques used in the product development to improve the assembly". The authors divide the DFA in three boardings:

- general rules used by the designers as directives;
- measurelines of assemblability of parts and the product as a whole;
- revisions of design to combine the measurelines of assemblability with times of assembly and its costs with assemblability rules in order to assist in the revision of the design.

Because of this, it can be defined some basic lines of direction for DFA: minimize the number of parts and easiness of assembly to reduce the cost of the product [18].

Thus, Kuo et al apud Valeri and Trabasso [18] cite the criteria of DFA as being:

- to minimize: number of parts and elements of setting, variations of design, movements of assembly, directions of assembly;
- to provide: chamfers, automatic alignment, easy access, symmetrical or to evidence anti-symmetrical parts, simple manipulation and transport;
- to prevent: visual blockages to parts, entangled or hidden parts, necessity of posterior adjustments in the assemblies.

So, we can note the capacity to integrate the product development process that the presented methods possess. From this, we can think about the best use of the same ones, suggesting to apply them in the interface design in the Conceptual phase.

FMEA

The tool of Failure Modes and Effect Analysis (FMEA) were developed with the intention of assisting in the diagnosis and forecast of military and aeronautical equipment imperfections. However, due to its predictive character, it passed to be used in product design.

The FMEA is a standardized analytical tool used to detect and to eliminate potential problems by a systematic and complete way [17]. It uses the knowledge of the design team on quality, performance and process. Moreover, the FMEA allows the hierarquization of the causes of the problems and establishes parameters for the adoption of preventive or corrective actions [17].

Thus, when the FMEA is applied, we can to determine the design critical points. This will help the team to define the priorities of design. This tool, as well as the DFA and the DFM, is used in the Preliminary Design phase. However, like the FMEA implies in functioning preview it is useful in the Conceptual Design.

The application of FMEA in the Conceptual Design possesss the advantage to detect and correct problem earlier. However, it presents the disadvantage of, in this phase, to possess few available information. This lack of information can be a source of uncertainties, but this can be useful in the interface design to solve some of the uncertainities.

4 Conclusions

For the analysis of above displayed it can be evidenced that the interface design and CE are subjects that look at different aspects of the product development. Although this they converge to the reduction of the uncertainties in the design process. This is because they involve people of different areas of the product lifecycle. So, they can to map and forecast neglected product aspects. However, there are barriers for use them.

Although sufficiently studied the CE still possesss a set of barriers to effectively be implemented. It cannot be used in many companies because is a work philosophy that must has a lot of information exchange and quarrels between different functional areas of the company. These experience exchange depends basically on the profile of the involved people in the design team. However, a difficulty can appear due to internal disputes or problems of relationship.

The interface design has another kind of implementation difficulty. There is not interface design methodologies for the conceptual design. There are proposals that suggest its use in the Preliminary Design. However, these keep the sequential status of the product development.

Based on these barriers, we perceive that there is a need to improve aspects of both the subjects. This improvement passes for the anticipation of the interface development to the Conceptual Design. This anticipation with concurrent application of the DFA, DFM and FMEA tends to add information of different areas of the product lifecycle facilitating the implementation of the CE environment.

This occurs because the DFx techniques can be considered as a knowledge base which objectives to design products maximizig characteristics as: quality, reliability, services, security, user, environment, time-to-market, at the same time that it minimizes costs of the product lifecycle and manufacture. Thus, the use of the DFx in the Conceptual Design can have a great role in the taking of abstract level decisions and in the product costs later phases of its development. In addition, they define the product performance in its lifecycle.

The use of DFA, DFM and FMEA in Conceptual Design is a new perspective in the field of integrated product development, therefore it can use all the advantages that those tools present in relation to the type of knowledge used in the generation and election of product concepts. This because, being the same exposers of the tacit knowledge, they can contribute for the diffusion of the experts knowledge for the whole organization.

Thus it is evidenced the viability of the use of the techniques with indicative for possible works in the Artificial Intelligence (AI) area. This is because AI permits to deal with the tacit knowledge of the human being transforming it to explicit knowledge. In addition, the AI is in a certain form, linked to the problems of heuristical nature as the election of the best conception for a product.

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