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DESIGN METHODOLOGY FOR SOLVING UNKNOWN PROBLEMS IN THE MODELS AND PROTOTYPES DEVELOPMENT LABORATORY OF THE UNIVERSIDAD SIMÓN BOLÍVAR

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ABSTRACT

The Models and Prototypes Development Laboratory of the U.S.B. was founded 17 years ago, being its main purpose, giving direct support to student's projects of Mechanical Engineering, participating in the Design Methodology course. Currently, this Laboratory works also, as a link between the U.S.B. and the country's industrial sector, providing solutions to designing and building machine, particularly for medium and small size national industries.

The project's typology that is normally solved in such Laboratory is related to unknown solutions, that is, new solutions, adapted to the special needs of client enterprises. Consequently, solutions are produced in a joint fashion and in small series. All this, has crystallized in the development of an original Design Methodology, based on the accumulated experience of both, the design team, and the decrease of risk related to particular problem solving.

This article, presents a description of each and every phases, steps and stages, implemented in the Design Methodology utilized in the Models and Prototypes Development Laboratory.

Keywords: Design methodology, problem solving

1 INTRODUCTION

Design has multiple applications on many different fields, and each one of these has its own needs, limitations, goals and rules. Generally, any item, product, or process conceived has been the result of design. Design is thus, one of the many displays of human creativity, which allows the construction of items, machinery or processes that aim at improving quality of life.

Design consists in adapting products to specific circumstances. In a changing world, products also have to change [1]. The real issue emerges when we try to teach students to learn how to design, how to solve new problems, or how to find new ways to solve them. That’s what we seek in The Design Method Course, which is obligatory in the last year of the pensum of the Mechanical Engineering Career. In this course, different design methodologies belonging to several authors are studied, along with a series of methods and tools necessary for each step of the design process, divergent and convergent, aiming at the selection of the best solution.

It has been said that, the mere fact of following a design methodology limits the solution field, making impossible the production of completely new concepts. We have always tried to solve the paradox of whether limiting creativity or not. Creativity does not mean

improvisation, on the contrary, it means being constant and methodic. The methodological approach for a designer, is not an absolute and unchangeable object, it is rather, something modifiable that leads to eventually find other feasible paths to improve the process itself [2].
Many authors have proposed different methods to manage the design process, that provide a series of steps or stages, through which we transit by the process of finding correct solutions to different problems. Using such methodologies is not a restrictive practice; on the contrary, they have to be adapted to each situation, and to each individual profession. The "paradigmatic" design method for producing correct solutions to any problem does not exist. The majority of such approaches coincide in some steps. A number of them give more importance to certain stages, some do not. Depending on each individual experience, and on their specific field of expertise, they have produced diverse approaches to the design process [3].

2 MAIN FEATURES OF PROJECTS DEVELOPED IN THE LABORATORY

Generally, from the innovation standpoint, we are able to classify problems as: original designs, adaptation designs, and variant designs. From the manufacture standpoint as: products manufactured by system or unit machine, manufactured in small and medium series, and manufactured in large series [5].
The Models and Prototypes Development Laboratory (M.P.D.L.) of the U.S.B. has located its workspace in the solution of industrial problems for some small and medium sized firms within the country's industrial park. These firms require different equipment developed and adapted to specific needs. This workspace is presented in the dark cell of Table 1.

Table 1 Workspace depending on innovation grade and manufacture type of Projects produced within the M.P.D. L.

		Product Origin & Manufacture Types		
		System or machine unit or manufactured in small numbers	Manufactured Products in small and medium series	Manufactured Products In large series
Innovation Degree of the Product	Original Design	(dark cell)		
	Adaptation Design			
	Variant Design			

The Table above shows that each particular problem will have a combination of situations which make it original, and in a way, unknown. This has to be precisely the center point of the designer. This fact shows a main need for a design methodology employed, which is to minimize risks and uncertainty levels associated with following unknown paths.
Experience is another factor to be taken into account. Although the most of solved problems within the Lab are original; accumulated experience represents a faint light to be followed in the process of finding new solutions. It is not advisable to get rid of past knowledge in the search for new paths and solutions.
One of the main starting points is to count on concrete and measurable results for each and every one of the phases, steps and stages involved. Analytic and comparative studies of different design methodologies [3], contained in the specialized bibliography [4-7], can be utilized as a guide to elaborate and adapt a personal design methodology fitting specific Lab problems. From this analysis, we obtain a five phases division: set up, conceptual, detailed, manufacture/test, and marketing/operative.
It is important to note that the students get deeply involved during the development of the projects. They participate not only on the methodology aspects, but also on the calculation of machine elements and mechanisms.

Besides, when students decide to make their thesis on the Lab, they acquire skills and knowledge on the use of tool-machines and the work's methodology of the Lab, by adding it in an effective way to their task. This is called *constructive learning*, the construction of knowledge related to previous experience.

3 A METHODOLOGICAL PROPOSAL FOR MACHINE DESIGN

Set up Phase

In figure 1, we visualize schematically the preparatory (set up) phase of the proposed methodology for machine design within the M.P.D.L. (U.S.B.)

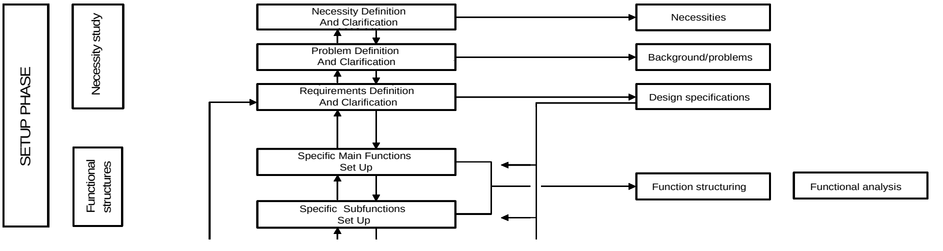

Fig. 1 Set up Phase

Within the first phase, we have a Needs Analysis step which starts with the definition and clarification of the necessity itself. That is to say, they respond to very specific necessities posed by specific firms. Sometimes it is essential to understand the firm's production process well, to define the exact nature of the necessity. The second step of this phase is: the problem's definition and clarification which focuses on the problem to be solved. This is basic to prevent loosing precious time and energy while solving another problem. It is also necessary to study the problem's background, that is, how similar problems have been previously solved, from other technical point of view. The third step comprises the requirements' definition and clarification. The problem is concretely defined by establishing its design specifications. From this step outcome a specifications document which will serve as a control element for the rest of the process stages. The next stage is the definition of Functional Structures. Here functions and sub-functions are clearly established to generate a functional tree, in which functions to be satisfied are established, ordered and connected to meet the proposed final solution [3].

Conceptual Phase

The Conceptual Phase Fig. 2 starts with the Conceptual Design Stage, which tries to establish the functional co-existence principles, in order to set up the basis for the correct fulfillment of previous stage posed functions. The next step is Modular Division, which concentrates functional structures in feasible modules, using formal, spatial, functional, and manufacturing criteria. Given the nature of design, there is some uncertainty in the development of a number of modules, due to both: the lack of experience and to technical difficulties. The design team sets up the critical modules, taking this into account.

The following stage in the Conceptual Phase is the Critical Modules Conceptual Design. At this stage, synthesis work and the search for solutions principles for critical modules is commenced. This step has to obtain a series of ideas that will properly express serve as foundations to cue requirements for critical modules.

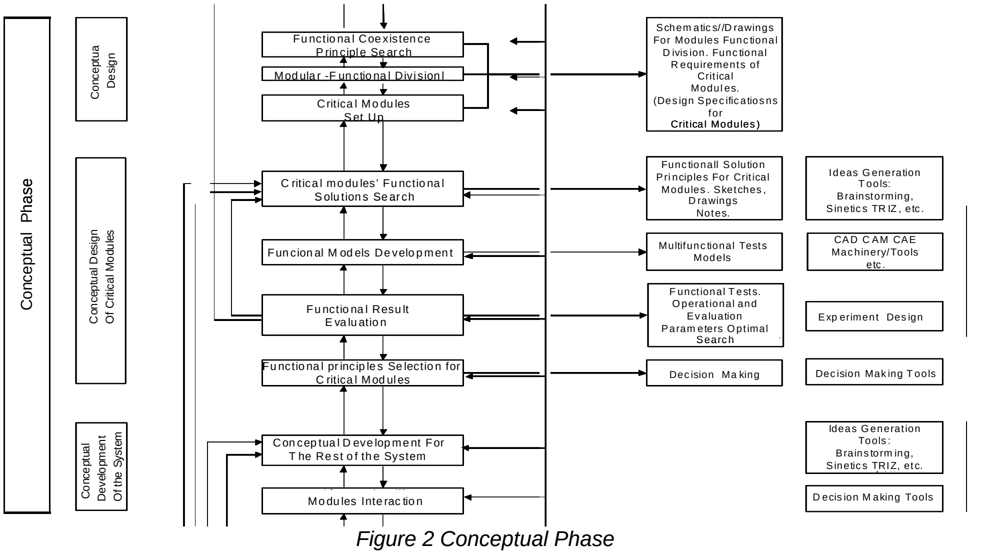

Figure 2 Conceptual Phase

This stage is fundamentally creative, and it implies the use of several methods for the generation of ideas. Considering the solution alternatives list for such cue modules, we proceed to Multifunctional Model Building, which aims at decreasing uncertainty in the design process while allowing the correct visualization of posed ideas, in order to clear out possible hurdles. Here it's shown whether previously posed ideas will work or not. During this stage, practical and sensorial thinking lead the action. Multifunctional models will be either physical or virtual. There are computational tools which facilitate a very good approach to reality, which is the main feature we look for, in the construction of these multifunctional models [3].

The multifunctional models produced, should be functionally evaluated, in order to guarantee correct requirements observance of critical modules. This step is fundamentally analytical and it includes setting up proper evaluation tests for these models in search for optimal operative parameters, based on diverse experiments design tools. If results are not satisfactory, it will be necessary to go back to the previous steps and select another functional proceeding. If results are satisfactory, more adequate functional principles are selected, at the critical modules' function principle selection step, with the help of decision making methods. Understanding and establishing functional principles for critical modules, before going into the following design stages, is essential. This will save much time and effort and produce feedbacks within the design scheme, along with their corresponding consequences [3].

Detail Phase

This phase Fig. 3 comprises only one stage: Detail Design, during which all modules are dimensioned, calculated, and specified in their construction and assembly. The result is a set of detailed manufacturing and assembly drawings and blueprints, a list of components and parts, control algorithms and programs, that is, all necessary documents for the physical construction of selected solutions. This stage is merely analytical, and comprises a series of decisions related to material selection, commercial parts, calculations, engineering estimates, etc.

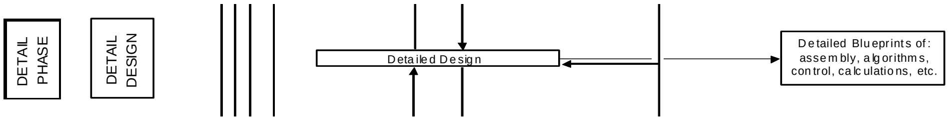

Figure 3 Detail Phase

Construction and Test Phase

In this phase Fig. 4, the project is materialized. The Prototypes Construction Phase begins with the building up of modules previously considered as critical, which after being evaluated could feedback or not the searching stages for solutions principles to the critical modules and, if necessary, produce a change in the selected principles. At the same time, manufacturing and evaluation of additional modules is carried on. This could, in time, feedback into the previous stage of Conceptual Development of the rest of the System, only if any change on the functional principles is required. Following the completion of assembly, we proceed with the final evaluation. The step in which fulfillment of every previously established specifications is revised. The Prototype Construction stage directly influences on the Detail Design stage, for while constructing, details could emerge that eventually may feedback into previous stages [3].

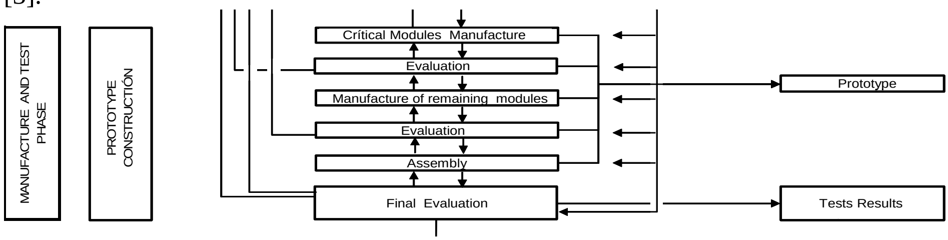

Figure 4 Manufacture end Test Phase

Manufacture and Test Phase

Operation and Maintenance of developed products will very probably be in the hands of people non-related, whether directly or indirectly with the design activity. Consequently, operational and maintenance handbooks, properly drafted in a language that could ensure a correct understanding are needed Fig. 5.

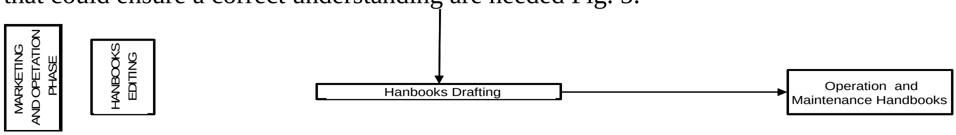

Figure 5 Marketing and Operation Phase

Figures 1 to 5 show the existing interaction between each one of the steps is visualized, as well as their influence on the previous process. For instance, after evaluating models' results, the previous stage of functional principles search for critical modules will be modified, depending on the particular situation. In this manner we can obtain a complete iterative and interactive diagram, along with all its parts.

Among the previously posed requirements, we find the accounting for accumulated experience by the design team. This experience sometimes manifests itself in an emotional and intuitive fashion. This in turn, complicates its operative application and rationalization. In the development stage of multifunctional models, which is oriented towards solving basic problems of modules defined as critical, it is possible to express such kind of worries, allowing the designer to build up a functional model that shows his viewpoint, even if it is considered intuitive. Equally, in the correspondent steps to modular functional division and to critical module establishment, it is essential to account for the design team's experience. Reducing existent risks and uncertainties within unknown (original) problems solving is achieved by the design team through implementation of the corresponding steps for developing multifunctional models, and through functional evaluation of critical models. In these stages, the functioning of development's cue parts is achieved in a practical, coherent and concise way. As a consequence, the uncertainty level diminishes significantly, and it renders unnecessary finishing the process completely, to predict the prototype's behavior.

The design and construction of multifunctional models constitute the basis for this proposed methodology. Such models, allow predicting with some degree of accuracy, the functioning of the machine as a whole. This has to be seen as a valuable design supporting tool and, we should not go further into the following process steps without completing tests and evaluations adequate to the model itself.

4 CONCLUSIONS

Conceiving, registering, drawing, explaining, or patenting an idea, depending on each particular case does not solve the problem in its totality. It is necessary to implement, construct, test, and evaluate the idea itself. This methodological proposition offers a guide by a series of stages, which can lead the designer to the solution of the problem. The reach and extent of each stage will be directly related to the nature of the problem. This shouldn't be seen as a strict design methodology but as a campus that shows the right path to be followed. The interesting and motivating facets of the project activity consist in acquiring knowledge after having gone through the design process path. This represents a continuous learning action. Even if we count on vast experience in a specific field; the solution of problems always goes through some original facet, which inevitably results in knowledge. The most significant aspect of such a learning experience is that: it is generated and constructed by the designer himself. This constitutes what the psychologists call *constructive learning.* The construction of knowledge related to previous experience. The students that make their thesis on the Lab successfully apply this methodology.

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