

## **A GENERAL APPROACH TO THE PRODUCT CONCEPTUAL DESIGN PHASE**

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**Abstract:** This paper's aim is to support the product design process in education and proposes a general approach to product conceptual design phase in industrial engineering. A first review of design models and methods is done, then are highlighted several existing design problems seen from the industry and education perspective found in literature. The last part presents an approach that contributes to the mindset and understanding of the products' conceptual design phase in industrial engineering and that can be successfully applied in practice.

### **1. INTRODUCTION**

Engineering design comprises all lifecycle stages from the needs analysis to its recycling and disposal. Specialized literature divide engineering design in different phases but it is accepted that there exist three main phases: early design, detailed design and design analysis.

Modeling process of design and innovation is changing; new and new works on this theme is developed. There is no single model, widely accepted, even if the design domain interferes with many technical or less technical fields. In addition, the methods used in the design field are many and varied. In these circumstances, the question arises as which particular models of conception and which ones of the design methods are considered most valuable to be learned by students and next to be used in industrial practice.

### **1. PRODUCT DESIGN MODELS**

In previous works were analyzed different types of design models that can be met in specialized literature. Most widespread models of product design, found in the literature are:

**Pahl and Beitz model** [8] – is based on phase notion and on the design seen as hierarchical sequence of stages, the predominant logic is the convergence. This model "did not attempt to have the last word on the subject, trying to be good in design practice and education, to provide a range of methods used in design, to highlight the importance of fundamental knowledge, principles and guidelines and be useful as a guide for designers and managers in the successful products development, it is not based on a specific method, but applies methods more or less known, where they are appropriate and useful for specific tasks and working steps".

**DFSS model** [19] - is a model based on domain notion and it contains a design algorithm based on Design For Six Sigma approach where the life cycle of a design entity is formed and shaped usually in phases and "barriers". Phase is a set of development activities and bordered by an entry and exit. The algorithm has four phases, called generic: I-identification, C-characterization, O-optimization and V-validation.

**Axiomatic Design model** - is based on domain notion and the design consists of two processes, creative and analytical [14]. The creative one leads to new solutions, while the analytical evaluates new solutions and leads to rational decisions. Axiomatic Design (AD) is considered useful in the analytical phase, not in the creative one. To achieve its purpose, AD provides a systematic search process in the design space to minimize the

random search and determine the best solution among several alternatives. It is not a mean to find solutions for the problems, but is used to achieve the functional structure of product model. AD treats principles and methodologies, rather than algorithms or means (tools). Based on two axioms, theorems and corollaries are derived and thus are developed methodology based on functional analysis and minimizing information that leads to a Robust Design [15].

**The New Products Design (NPD)** [2] - is based on domain notion using the integration of expert skills into a multidisciplinary team and uses a series of methods that enable a good collaboration between the different team's members and guide them to obtain innovative products. This model emphasizes also the importance of taking users into account during the design process and comprises four phases that are need translation, need interpretation and solution's development and evaluation (or validation).

In addition can be mentioned models based on phase notion: French's model [4], Roozenburg and Eekels model [13], March's model, Ulrich and Eppinger model [18], Ullman's model [17], Pugh's model [11], models based on activity notion – EVAD model [1], Purcell's model [12], Girod's model [5], M3M model [7], models based on domain notion – FBS model [6], design rationale models, Nord Europe models, value model [9] co-evolutiv model.

In models based on the notion of activity, unlike those based on the phase notion, the emphasis is on observing the design work and take into account the human element, their expertise of those involved and highlights the need to observe how decisions are performed by designers during the design process. In other models, designers see the design action as an action on some attributes that you manipulate (size, specifications) and other attributes that influence their decisions and activities such as, performance. In most models also are indicated the design methods that can be used. Thus, there are many methods used in the design and the most common used are: Functional Analysis, Morphological Charts, Brainstorming, Literature search, Patent search, Design Catalogues, Evaluation Matrix, Object Tree, Quality Function Deployment, Design for Manufacturing, Design for Assembly, Statistical Process Control, Simulation, Design of Experiments, Value Analysis, Rapid Prototyping, Failure Modes and Effects Analysis.

### **3. DESIGN MODELS AND METHODS IN PRACTICAL AND EDUCATIONAL USE**

It is very important to understand the design processes as being articulated around three classical components: divergence - phase in which all psychological barriers should be passed and deep thinking should lead to the development of bold solutions; transformation – the stage when reasoning about values and technical aspects are combined in the form of decisions and convergence - its purpose is to reduce the secondary uncertainties progressively until only one of the possible designs remains final solution and is to be launched in practice.

Common aspect of most models is that they provide a framework for defining and planning current and future actions. Although these models treat the same subject and the application's purpose for a model or another wants to be the same - a simple product, quality, at a low price and in short times, the problem is seen as that these models are very abstract, can be applied in many areas as general guidance, but it requires a more precise orientation. The question that arises is which one of the design models is the best for students training.

In [16] is discussed the gap between practical and educational usages of different design models. The Pahl & Beitz systematic design is a methodology widely used and learned and served as a base to VDI and Pahl & Beitz's model is seen as a unifying factor

in creating a general design approach [16]. Axiomatic Design is also one of the methodologies spread in academic domain and a wide variety of its industrial applications can be found [20]. Axiomatic Design is not such an easy method, it has to be learned first and it seems to be difficult at first sight. In addition, about this method in [16] it is said that if this methodology is not enough studied in academic process of student's formation this conducts to its unused in practice. It is also presented the idea that the industry estimates that the students are learned theories and methodologies that are useless when they are confronted to real design work. The number of design methods met in many engineering design fields (and not only engineering) is very large. An introductory course is not enough to sustain these methods use and then their use in the correct place.

The design methods used vary from one model to another and, in this context, adaptation and selection of appropriate methods require students' knowledge in the field of each method; so these methods have to be first learned, trained, and applied. Moreover, the domain where is used the design process and even the engineering direction where it applies influences the approaches and methods use. The design process's aim is to „say” how things have to be done. Because designers are the actors in design process, the design activity depends upon their views and values and also design problems identification, their solutions, the way how these are achieved are all depending on designers' perspectives [3].

The design process is seen as a set of activities where are developed and chosen the means to achieve a set of objectives, depending on requirements. The design may represent the finding of a new solution, selecting an existing solution or a combination of both and there are many design methods used, depending on the area in which design occurs, depending on the approach used, depending on the type concept - the new product or re-design of a product.

In the following, a general approach to the product conceptual design phase in industrial engineering is proposed. In practice it is needed the right “tool”/method at the right time and there sometimes is not time to make a wide bibliographical research and time to learn then apply a method. The advantage of this approach contributes to a mindset and understanding of the product conceptual design phase in industrial engineering and can be used successfully in practice:

1. Set targets;
2. Delimitation of the proposed topic;
3. State of art on the proposed theme - specialized research references - articles, PhD theses, patents, etc.;
4. Study on the possibility of achieving technology - methods / procedures, the range of types and sizes;
5. Summary information on processing devices that support the chosen technology and installation devices:
  - a. study known constructive solutions;
  - b. morphological research of constructive solutions (morphological charts);
  - c. comparison of known constructive solutions:
    - i. Criteria for evaluation and their order of importance;
    - ii. Comparison of known solutions;
    - iii. Ordering critical value of the known solutions and their critic.

If is considered the development (proposal) of new possible solutions, it can be continued with item 6. However, to draw up new solutions all design methods that contributes to the creative thinking development are welcome and, for example, TRIZ [21] (Theory of Inventive Problem Solving) plays an important role in this, but to use the TRIZ

methodology one has to know it and this requires a thorough study and experience in its use.

6. Developing new solutions for devices:
  - a. a research-based orientation is to compare solutions starting at point 5;
  - b. morphological research of constructive solutions by lexicographically ordered listing;
  - c. advantageous solutions comparison;
  - d. optimal solution's setting.

#### **4. CONCLUDING REMARKS**

Considering the above, we believe that in the education of future engineers in order to understand the complexity and size of the design process is important to study general design models and then, in particular, the design methods. To decide which ones are most important methods in the design it would be interesting and important to know the methods that are used most in the industry.

The paper proposed a general approach in support of education and practice and this is not restricting the opportunity to deepen design methods practice and without minimizing the importance of studying design models and design methods.

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