13th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

INTEGRATION OF FUNCTIONAL DESIGN AND DESIGN BY MEANS OF BOND GRAPH

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ABSTRACT
In the process of product design in mechanical engineering and mehatronics there are two types of approaches to design, functional design and designing by bond graph. In this paper, we will focus on combining these two approaches of product design within different areas of designing. Integrating of these two approaches whereby, we will get a new approach to design representing a symbiosis, for the purpose of seeking for the optimal design, selection of technology and finance aspect of a product as well. In a word, combining these two approaches would stir up a new approach giving us better and more comprehensible problem solving solutions in terms of a product design in a very complex environment.
Keywords: design, product, mechatronics, bond graph

1. INTRODUCTION
The process of designing devices for the needs of a modern man is a complex problem, whereas each device consists of a number of mechanical, hydraulic, pneumatic, electrical, electronic and other parts that make a functional whole. With reference to the share of electronic components in a technical system, its design can be realized through the access to the distinctive design of mechanical or mechatronic systems, having the phases presented in the below table 1 [1,5].

Table 1. Designing phases in mechanical and mechatronic system

Mechanical system design phases	Mechatronic system design phases
Defining the project task	*Mechanical system*
Conception	*Adding sensors, drives, microelectronics, control devices*
Forms and sizes development	*Components integration*
Status and correction analyses	*Information processing integration*
Constructive elaboration	*Mechanical system remodeling*
	Synergic effect
	Complete integrated effect

Designing machines and devices through the mechanical system design phase gives satisfactory results for systems having a low level of integration of electrical and electronic components, and the basic part of the machines or devices are mechanical components. Products designing through a systematic approach provide straightforwardness in the design including all components taking part in the product. Also, different ways, approaches, schematic views and the design control are considered at the occasion of systematic approach to design. Notwithstanding it all, mechanical system design presents basic design process. Project design access through mechatronic system design phase is very complex. Mechatronic system means the combination of mechanics, sensors and drives, programming and data processing, computers and logic systems, signals and systems, but the design approach is deductive and provides opposite direction in the design.

Developing the functions in the subfunctional units i.e. so-called substructure as well as substructure in the elements, means a way to a system design. This design is called functional decomposition. In addition, this design approach gives a good perspective in implementation of the requirements presented to developer or designer and it is known as the design "from the top to the bottom". The opposite process is called functional composition. This procedure is opposite to the above mentioned and it is called the design "from bottom to top". Therefore both approaches to the design are considered as the access types.
Design of mechanical system covers a number of systems for graphic display of the flow of functions, data and information developments. Therefore, relation systems, flow diagrams and other graphic presentations are elaborated for that purpose in order to present functioning of a system and processing of all information and data as food as it can. In this paper, it will be made the model of products design that will satisfy both approaches of the designing through a practical example.

2. PRODUCT DESIGN MODELS, ILLUSTRATIONS AND METHODS

In addition, logical, relational and functional models are developed, being based on discreet mathematics, in order to display graphically connection between functions. Graphical display of the functions can be presented throughout following graphics [4]:

- lines,
- rings,
- tree
  - spread tree,
  - direction tree,
- forest.

These presentations define position of each function, its subfunctions within which flow of energy, data, etc is defined. Developing the subfunctons at the features representing the elements, it is required a logical flow of energy, effort and data. Since we have needed control of these elements, therefore the formatting the interface feedback should control the output and input from one to the other element and thus transfer valid variables in order to avoid errors in the system. Due to these facts, there are [1]:

- open loop of process control
- closed loop of process control.

This is not only to define the very process but also to compare the input and output entry. Therefore, graphic models displaying the functions developing are produced on the basis of the following [4]:

- graphical display of modeling data flow
  - Entity-Relationship diagrams - give a structure or relations between elements,
  - Higraph - performance pointer giving the suggestion that contain links or relation between the functions;
- graphical presentation of the process modeling
  - data flow diagrams - show the flow of data and information between the functions,
  - N - Square (N^2) graphics - the flow of data at the entrance and exit between subfunctions in the process of developing a functional architecture by decomposition;
- behavior model
  - diagrams of behavior - behavior of function in progressive development of hierarchic functions by decomposition and their entrances and exits through the function,

- state-machine diagrams and state-flow – it is operated with discrete values of inputs, outputs and interface as well, while the state-flow operates over the state of machines over the relevant time,
- graphs state - is based on the graphic and spreadsheet display of the variables and is based on state-flow,
- control flow diagrams - used to control data flow diagrams presenting the model of changes through functioning of system,
- Petri Nets - are drafted on rigorous mathematical system that leads to the simulation and has formal mathematical characteristics.

From these diagrams it is the developed impression of energy flow, effort and data throughout the substructures, structures and through the system in its entirety from the entrance to the exit.

Product design through the mechatronical system design phases creates the system of composition. It is designed at the level of elements and on the basis of their connectivity should be formed the sets - substructure, then from the substructure it is formed structures and then comes a whole system i.e. set. Design is based on the concept of bond graph having elaborated system of marking, joining and designing the elements in the functions. Very important relation in the bond graph is effort and the flow of energy, which represent the power that is distributed through the elements because effort and energy are transmitted between the elements. This approach allows connecting different components in a set, for example, from mechanical to hydraulic, and further from hydraulic to electrical. According to this, the components are very flexible in the process of connecting. It is necessary to overlook the flow through the design phases of machatronical system that lead to the achievement of synergy effect, and then connect to the interactive control console and get ready system, which has management systems, control and diagnostics.

3. FORMATION OF DESIGN MODEL

Having insight into the design phase of mechanical and mechatronic systems, it can seen as common element mechanical system and remodeling of machanical system, but mechanical system design is presented in a series of steps to forming a unit, while in the stages of mechatronic design it appears in two steps. Considering the complexity of design and construction, it is necessary to notice that mechanic system design is a basis for designing both systems. Featured models for diagrammatic expressions are seamless not having the possibility of processing the large number of parameters. It is caused due to on abstract level of design, parameters are not given and considered intensely as regards variables essence within the system, but only the logic of the functioning is being elaborated in details, but mechatronic design model does not provide an opportunity for the selection of favorable variations, technological and economic aspects are not regarded as very important.

3.1 Model design

Based on already said facts, we are familiar with following parameters: effort, flow and data. We will use the conventions of bond graphs for showing graphic presentation of effort and energy. It shall be used half open or open half arrow pointer, depending on the number of the entrances are in the function, as a way of recording controlled variables. It is recorded detachment point as a 0-junction for the flow of energy and 1-junction for fork of the effort. As regards the flow of data, it is used full arrow pointer that shows the movement of data to be controlled, observed, read, or processed, while it shall be written controlled data next to the line of data flow, above or below it. Description of the element i.e. subfunction shall be defined in the rectangle representing the black box of elements processing which could be combined during integration system process and it shall be separated by full line if there is a direct and necessary connection to the sensor. Therefore, it allows combining the mechanical elements and electronic components with mechanical parts within the same scheme regardless it is about the sensors, drives, or any electronic circuits that perform some functions.

3.2 Developing concepts on subfunctions - case study

In the design of products for one customer, we make the product design through the process of flow of information, effort and flow of energy. The structural variants I and II, which were drafted and the

selection are made on the basis of experience and previously developed systems that are directly applicable to this problem (figure 1).

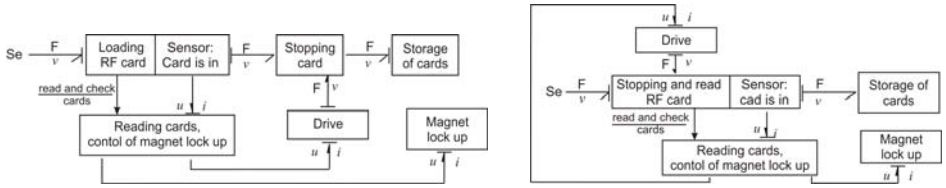

Figure 1. Developing products into developed functions I and II

Above mentioned subfunctions are formed and developed according to the cause-consequence principle. Treating it in this way, we get the product developed functional architecture – by decomposition. From the mutual relation between the elements it can be seen which elements can be developed. Also on the basis of functional units valuation and selecting the best elements, the relevant elements are developed. This shows that when combining the elements in the morphologic box, it is needed to follow mathematical relations and geometry, and therefore the very process of combining is limited and flexible in a certain way. It is limited due to it is known what elements can be combined according to cause and effects method, and it is elastic due to it can be selected at least one combination that can be later treated in the process of selecting the best valuated physical concepts.

4. CONCLUSION

Why bond graphs are given in relation to the block diagrams? Non-causality, based on formulas, causality (one is input component the other is output component) of the very expression being pure; the transmission of energy through the nodes, which is automatically based on the laws of physics; brevity, each link knows two types of signals, the connection are local as well as the components; topology which is close to the real system with a graphic description established by convention; the subfunctions of causality are adaptive for repeated use. Block diagrams are general not giving following and control of the flow of several variable information. They are mainly limited to abstraction of functioning, the exchange of data in the process of functional decomposition and logic of functioning without entering in the nature of variable in process.

New model which has been developed by pairing the bond graphs and block diagrams provides data flow tracking, effort and flow between subfunctions in the development of functional architecture of a product. Subfunctions are defined through functional description of the words giving the possibility of development of elements and their pairing in the functional unit on the new foundations and flexibility in the design. Also, it provides the possibility of its implementation in the engineering design procedure.

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