DESIGN AND TESTING WAYS FOR MECHATRONIC SYSTEMS

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ABSTRACT

The elements of a mechatronic system, which are mechanical, electrical and electronic, are interconnected and the connection between the different parts must act as a unit. The exchange of information between two components of the system is possible if there is a communication in common parameters. The interface refers to all the ways to handle the processes in a system. The number and design of interfaces within an architecture and system boundary significantly influence the simplicity, adaptability, and testability of a system. Interfaces, which are hardware and software, define the functionality of the system by inserting functions from one component to another. The article describes the method of selecting the components and the way of testing the system during production. Finally, the system must meet the requirements of the customer. The mechatronic system discussed is an industrial product, created in a digital factory.

KEYWORDS

Mechatronic Components, Design Structure, Hardware and Software Interfaces, Multidisciplinary Integrated Design.

1. INTRODUCTION

Mechatronics is a branch of several engineering disciplines, focused on electrical and mechanical systems engineering. This is about robotics, electronics, computer, telecommunications, systems, control and product engineering. The term provides a basis for technical and practical considerations. Engineer Tetsuro Mori from Yaskawa Electric, Japan, introduced the term "mechatronics." Moreover, registered as a trademark under number "46-32714". [1]

The Japanese company later allowed the right to use the word in public, and after the term begin using worldwide. In dictionaries, the term officially appeared in 2005 in Larousse (France). Nowadays, the word is translated into many languages and is considered an essential term for the industry. [2]

The French standard NF E 01-010 (2008) defines mechatronics as an "approach to the synergistic integration of mechanics, electronics, automation and computing in the design and manufacture of a product to increase and / or optimize its functionality". Many people treat mechatronics as a modern word, synonymous with robotics or electromechanical engineering. The using of term mechatronics denotes a rapidly developing and interdisciplinary field of engineering. It deals with the design of products function based on the integration of mechanical and electronic components coordinated by the control architecture. [3]

As technology advances, the engineering fields have managed to diversify. The intention of mechatronics is to produce a design solution that unifies each of them. [4]

As a summary, mechatronics is a combination of mechanics, electronic and real-time calculation. As in figure 1, the integration of these disciplines denotes mechatronics.

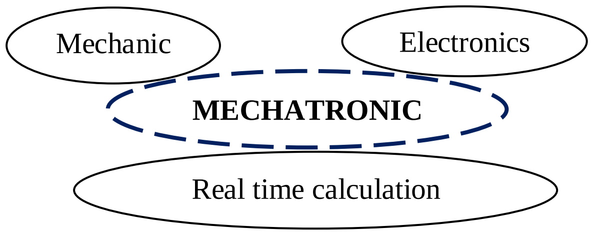

Figure 1. Approach to mechatronic discipline

2. THE EVOLUTION OF MECHATRONICS

Mechatronics is a technology that is constantly expanding. It refers to the design, manufacture and operation of the designed products, devices and processes, traced through:

- ✓ the industrial revolution (mechanization, water power, steam power);
- ✓ semiconductor revolution (mass production, assembly line, electricity);
- ✓ information revolution (computer and automation);
- ✓ the fourth industrial revolution (physical cybernetic systems).

At the industrial level, semiconductor and information revolutions have led to major technological advances in the design and operation of engineering products.

The disciplines of primary engineering - mechanical, electrical, civil and chemical have retained their individual body of knowledge, textbooks and professional journals, because the disciplines considered have an exclusively intellectual and professional territory. Those who study the field of mechatronics can assess their individual intellectual talents and can choose one of these fields as a profession.

This is a new scientific and social revolution, known as the information revolution, in which engineering specialization seems to focus and diversify simultaneously. The contemporary revolution initiated by the engineering development of semiconductor electronics, which led to a development in life-enhancing information and communications.

In recent years, the engineers began to develop highly efficient products and processes, carefully selecting and integrating sensors, actuators, signal conditioning, power electronics, decision-making and control algorithms, and computer hardware and software.

The stages of mechatronics:

- ✓ primary level mechatronics: integrates mechanical signaling with mechanical action at the basic control level, such as fluid valves, switches, relays, etc.;
- ✓ secondary level mechatronics: integrates microelectronics into electrically controlled devices, such as cassette recorder;
- ✓ tertiary level mechatronics: incorporates the advanced control strategy using microelectronics, microprocessors and other application-specific integrated circuits, for example the microprocessor-based electric motor used for robot operation;

- ✓ quaternary level mechatronics: tries to improve "intelligence" of the systems by introducing artificial neutral network and fuzzy logic and the ability to detect and isolate errors in the system.

The main concept of mechatronics is to work smart and efficient. In this way, we can obtain positive results in a short time. Mechatronics describes the combination of mechanics and work with precision engineering, sensor technology, actuator technology, computer science, and control theory and sensor technology.

3. THE ELEMENTS OF MECHATRONIC SYSTEMS

The mechanical elements that make up the mechanical structure, the mechanism, etc. form a mechatronic system. These may include static / dynamic mechanical characteristics and interact properly with the environment. The mechanics of mechatronic systems require physical power to produce motion, force, etc. [5]

Electromechanical elements refer to sensors and actuators. A servomotor turns energy into motion, also used to apply force. This is usually a mechanical device that takes energy - usually energy that is created by air, electricity, or liquid turned into motion. This movement can be in any form, such as locking, gripping or removing. Actuators are in manufacturing used or industrial applications and in devices such as motors, pumps, switches and valves. Most mechatronic systems involve movement or action of the same kind. This motion or action applies to any form until a large articulated structure.

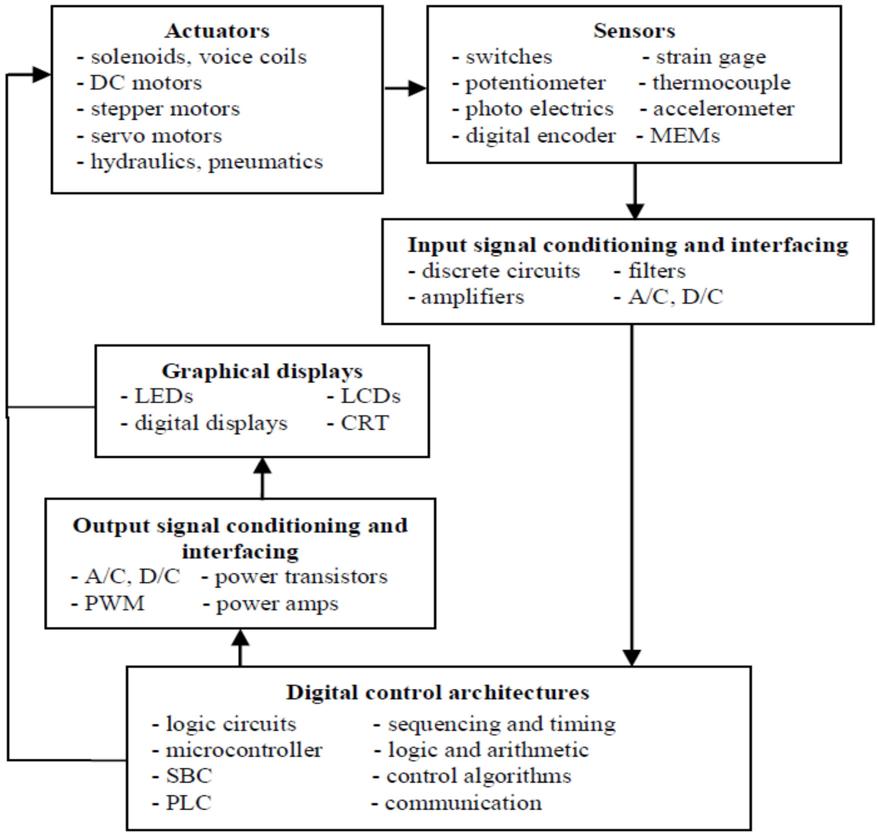

Figure 2. Elements of mechatronic systems

All these components controlled from a software program uploaded in a controller. [6]

Movement is by a force or torque created that result in acceleration and displacement. Actuators are the devices used to produce this movement or action. A sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and to send information to other electronic components, often a computer processor. A sensor is with other electronic components used. Electrical elements refer to electrical components (resistor, capacitor, inductor, etc.), circuits and analog signals. Electronic elements refer to analog or digital electronics, transistors, amplifiers, etc. The usage of the electrical / electronic elements is to interface electromagnetic sensors and actuators with the hardware elements of the control interface. [7]

The hardware of the control interface allows the analog / digital interface, i.e. the communication of the sensor signal to the control computer and the communication of the signal from it to the actuator. The control computing hardware implements a control algorithm, which uses sensor measurements, to calculate the control actions to be by the actuator applied. All mechanical devices include electronic components and some type of computer monitoring or control. Microcontrollers are more and more into electromechanical devices incorporated, creating much more flexibility and control in the design of the system. [8]

The digital factory offers a full range of services, such hardware, and software and embedded technology-based. This range helps manufacturers around the world to maximize the flexibility and efficiency of their processes, thus reducing the time to deliver on the market. Full integration of data on the industrial value chains is becoming increasingly critical for the sustainable development of manufacturing companies. [9]

4. Structure Design and Testing of the Product

Before starting the design of the mechatronic system, a person led the project of designing. This person is the project manager. The project manager (PM) nominated by the company at the latest before the launch of the project. If a project anticipates during the bidding phase, the PM nominated immediately and take responsibility for the project at that time. The project manager is responsible for leading the execution of the projects until the inclusive closure, in accordance with the contract, in the special performance and the program. He / she is the main representative of the company client and is responsible for making decisions on behalf of the companies within the rules of delegation. The responsibility covers the achievement of the results at the time of acceptance of the contract and is obliged to alert the management in case is any risk identified. This achieving is not during the daily activities. The differences between the signed contract and the initial offer, if any, identified at the time of signing the contract. The impact on departmental estimates and costs addressed at that time. Therefore, differences of this nature cannot occur for departmental cost approvals after signing the contract. However, management may request a review of the project objectives at the beginning of the contract. A system is from the point of view of several test models produced. The development models are different processes or methodologies that are for project development selected, depending on the goals and objectives of the project. It was many development lifecycle models developed to achieve different goals. The models specify the different stages of the process and the order in which they perform. The selection of the model has a big impact on the performed testing. It will define when, where and what from the planned test influences the regression test and determines largely which test techniques should be used. There are various software development models or methodologies, such waterfall model, agile model, incremental model, RAD model, iterative model, spiral pattern, prototype model, V-model. [10]

Thus, a product tested throughout the production process from several points of view. Depending on how and how much you want to test in the manufacturing process, you can follow a certain type of model. [11]

The mechatronic system considered is the resulting integration of the electrical / electronic system, mechanical parts and information processing. Therefore, in order to allow a systematic process of designing mechatronic systems with a high level of integration, the so-called multidisciplinary integrated design needed. In accordance with systems engineering practices, an extended "V" model used as a macro-level process in the proposed design methodology. It starts with identifying system-wide requirements and ends with a user-validated system. The hierarchical design model adopts a micro level process. It supports specific design phases in which individual designers can structure sub-tasks, proceed, and react in unforeseen situations. In order to ensure coherence and traceability between the two levels, the multidisciplinary interface model proposed. This design methodology demonstrated by studying the design process of a mechatronic system. Any of the models presented above used to test the state of a mechatronic system. Of course, depending on the test model chosen, there are certain advantages or disadvantages. The design methodology presented adopts the extended “V” model as a macro level process and the hierarchical design model as a micro level process. In a multidisciplinary way, the interface model helps designers ensure coherence between the two levels. [12]

The macro-level design process has adopted an extended "V" model process to present the overall flow for the mechatronic system. The left branch of the Model V extension represents the system design sub-process and described in qualitative models. After analyzing all the requirements for the whole system, sub-functions and subsystems defined. [13]

During the system design sub-process, design phases identified are the specification phase, the functional model phase and the architectural phase. As an adaptation from VDI 2206, it was created the model phase from figure 3. [14]

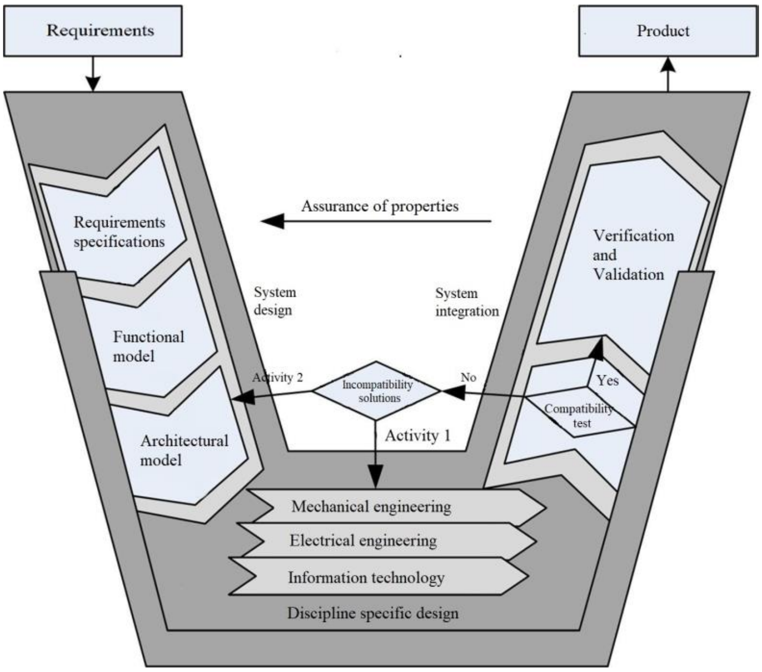

Figure 3. Testing methodology for a mechatronic system

The discipline-specific design sub-process presented at the bottom of the extended "V" model. It is the obtaining of the physical elements of the system such as hardware components or software code. The subsystems have a very specific discipline and different design teams develop those simultaneously. The models built by the teams in the different disciplines are largely quantitative. The right side of the "V" model is the sub-process integration system.

In the extended "V" model, this sub-process divided into two phases:

- ✓ compatibility test;
- ✓ verification and validation phase.

The objective of the compatibility-testing phase is to ensure the right and multidisciplinary integrated subsystems between different design teams. If the subsystems prove to be incompatible with each other, then the iterative process continues. This test compatibility in the early stages of system integration will significantly reduce the number of iterations in the later phase, so that overall development costs and time to market may decrease accordingly. Verification and validation at this stage used to test the integrated performance of the system and verify that the system is working and meeting all the requirements previously proposed according to the designed plan. If the system needs to be improved, the previous design and phases repeated. The macro design process is developed and based on the "V" model, which considers one of the most typical approaches to systems engineering. Therefore, the main design sub-processes (system design sub-process, discipline-specific sub-process and system design and integration sub-process) of the macro-level process are organized sequentially in line with practical systems engineering. However, designers from various disciplines perform concurrent design activities in each sub-process of the entire process to achieve better results. The organization of design activities within the same sub-process called the micro-level design process. The hierarchical structure applied in the three phases of the system design sub-process. The design parameter hierarchy proposed to help designers define key parameters in specific sub-process disciplines. The requirements specification derived from all mechatronic system requirements and they can provide initial information about what customers are asking for. The requirements may apply to the general system, each subsystem (or component) and the interconnection between two subsystems. Therefore, the requirements detailed by breaking them down into additional requirements, thus creating a hierarchy of them.

Requirements classified into several types:

- ✓ global requirements;
- ✓ cumulative requirements;
- ✓ specific requirements;
- ✓ interconnected requirements.

A functional model refers to the modelling and specification phase of functional solutions. The functional model plays an important role during the system design process because is built as a bridge between customers and the mechatronic system. From one side, the functions and sub-functions proposed in the functional models used to meet customer requirements. On the other hand, the architecture of the system established on this functional model. In this design phase, functional models of mechatronic systems created. They must meet the specifications and requirements so that they provide us with the basis for functional structural derivation. The hierarchical structure used for functional modeling. If a complex mechatronic system assumed to comprise a number of elementary functions then the functional structure of cooperation among these elementary functions considered. A single elementary function is characterized by the primarily use of a clearly defined effect (e.g. physical, chemical or biological) that can be considered as indivisible in the set of functions. Therefore, an architectural model consists of the grouping of the sub-functions of the functional model in order to implement the proposed function. After the process of hierarchical decomposition of the function, the designers should implement the subsystems into the proposed sub-functions. In other words, these subsystems should have decomposed sub-functions so that there is coherence between the functional model and the architectural model. The complete architecture built is in the direction of breaking down the subsystems to the architectural model phase. As a result, the decomposition process must be applied recursively. However, there is always a research question as to what hierarchies and granularities are appropriate for architectural models of mechatronic systems. To answer this question, the authors help designers find out how systems can be broken down. In the proposed architecture of the hierarchy, the system presents from top to bottom as a mechatronic system, mechatronic mode and specific discipline-component. A mechatronic module defines as a mechatronic subsystem at the lowest hierarchical level of the mechatronic system and is indivisible within the set of mechatronic subsystems. "Indivisible" means that the mechatronic module can only be broken down into specific (non-mechatronic) components, but not into other mechatronic modules or components of the mechatronic system. The discipline-specific components are the lowest level of system architecture considered. "Lowest level" refers to the components which standard components obtained previous designs or within the specific disciplines of the team. In the decomposition process proposed in two stages, the mechatronic systems altered into mechatronic modules. At this stage, designers should consider their design experience. For example, the mechatronic module based on the previous design or the standard component contains certain modules made in previous projects or uses standard components. This means that it is not necessary to break down a system into a database with discipline-specific components. However, in such a scenario, graphics or standard components are not always available. When there are exceptions, the second stage of decomposition repeated. Thus, the mechatronic module divided into discipline-specific components obtained with standard components, previous projects or discipline-specific teams. Once the mechatronic modules divided into discipline-specific subsystems and engineers develop their interfaces during the phase-specific design.

Two solutions presented to deal with interface incompatibilities:

- ✓ solution 1: change one of the two components related to the interface; compatibility should therefore check again; the solution call "component change";
- ✓ solution 2: decomposition of the interface into a component-structured interface; compatibility should be checked for the two newly created interfaces; the solution call "interface decomposition".

When the interface decomposition solution adopted, the design process should return to the architectural model. Therefore, the interface decomposition solution used as an effective support to help designers refine the architecture of the mechatronic system. The second reason is that the interface breakdown solution can help designers avoid design conflict. In a complex mechatronic system, one component connected to another through several interfaces. If the component changes, the solution adopted by the designers to resolve the possible incompatibility is to link other interfaces to this component that prove to be compatible. This is what to avoid any incompatibility after changing such a component. Such situations can always exist during the design process. The interface decomposition solution does not create incompatibility design because the new component does not affect other components of the system. If all interfaces in the mechatronic system shown to be compatible, which means that all components properly integrated with each other, the design process checked and validated. The verification and validation phase used to test the performance of the integrated system and to verify that the system performs the proposed function and meets all the previously proposed requirements. If the system needs upgrade, the initial operating phase will be repeated.

5. CONCLUSIONS

In the process of creating the mechatronic system, the role of the project manager as well as the team is very important. Clear requirements from the customer are the benchmark. The design team needs to study the international requirements for the product created. Otherwise, we cannot meet certain requirements. Likewise, choosing a method that is too simple to manufacture and lacks testing (such as waterfall) for a complex system can lead to extra work as well as scrap etc. Choosing a complex model for a simple model leads to a loss of resources.

Some rules are very important in setting the objectives of each project:

- ✓ understanding the customer's needs, knowing the products of competitors and deciding in which direction you want to differentiate the product from competitors (production period versus attractiveness, cost, quality);
- ✓ adapting and improving the internal process, as well as the practices and tools used;
- ✓ creating alternatives, understanding the associated trade-offs against excessive engineering;
- ✓ putting technical expenses under control;
- ✓ collaboration, communication and elimination as much as possible of losses, unnecessary work and recovery of non-compliant products;
- ✓ valuing and sharing knowledge in a reusable format;
- ✓ skills development and team leadership;
- ✓ management of product variability and optimization of deviation from products to projects (standard product for project A, B, C ... n);
- ✓ ensuring the organizational balance between product, project and engineering discipline;
- ✓ knowledge of new technologies and consideration of disruptive elements.

The strategy chosen from the beginning, based on the company's rules is very important, and the resulting finished product needs to have the desired qualities.

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