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1. DESIGN OF MECHATRONICS SYSTEMS USING CAX ENVIRONMENT

Modern mechatronic systems are a combination of mechanical engineering with electrical/electronic devices integrated by control as one real system. On the other hand, we can define mechatronic system as an intelligent connection of physical components (hardware) with information processing (software) [4, 10]. The word *Mechatronics* is described by Harashima, Tomizuka and Fukuda in 1996 [8] as: *the synergetic integration of mechanical engineering with electronic and intelligent computer control in the design and manufacturing of industrial products and processes*.

As suggested by Bishop and Ramasubramanian [1], mechatronic systems can be divided into the following modules (subsystem):

- physical systems,
- sensors and actuators,
- signals,
- computers and logic systems,
- software and data acquisition.

The complexity of mechatronic systems, resulting from the interaction of subsystems from various disciplines, requests the use of a proper, multidisciplinary design methodology and appropriate CAx (Computer-Aided technologies) tools [7, 15]. Coupling of modelling and simulation tools from the different areas of mechatronics in MCAD (Mechanical CAD) system is one of the important points to decrease the time of product development [9].

Nowadays, in addition to specialized companies, technical universities have become serious competitors in the progress of mechatronic systems. This is possible mainly because of development of new materials, manufacturing methods, computer technology and electronics. Modern computer-aided design tools are widely available and are used by both industries and universities for modern engineering education [6].

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The information technology revolution, wireless communication, MEMS technology, and the development of multidisciplinary approaches (Fig. 1.1) allow the creation of new solutions [13]. Future will be dominated by mechatronics.

In this paper, functional workflow in mechatronics design process between MCAD and ECAD (Electrical/Electronical CAD) tools in one CAx environment is presented.

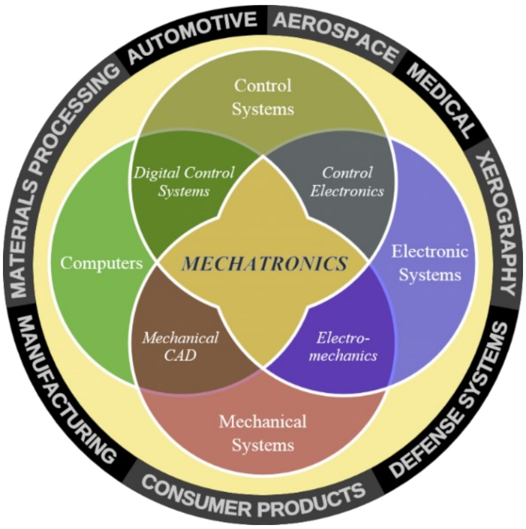

Fig. 1.1. Mechatronics system's components in a multidisciplinary space [16]

1.1. MECHATRONIC DESIGN

1.1.1. STRUCTURE OF MECHATRONIC SYSTEM

The main structure of the mechatronic system is defined by the following components: the system, the actuators and the sensors connected by the information processing unit. A flowchart of typical structure is presented in Figure 1.2.

The system unit has generally mechanical, electromechanical, hydraulic or pneumatic structure or it can be a combination of them. It means that a specified physical system can be understood as a particular system that can be characterized by a hierarchically structured system. The aim of *the sensors* is to determine a chosen state variable value of the system. The state variables can be understood as the physical variables fully determined for a sampling interval by their values at sampling time t_0. This ensures that the state variables for time $t > t_0$ are known. In this case, the sensors can be physically represented by the measured values or software sensors so called *observers*. *The sensors* supply input variables for the information processing, usually digital, i.e. discrete in terms of values and time. The information processing is done by a microprocessor although it can be also done by a fully analog or a hybrid analog/digital electronics. It determines actions needed to affect the state variables of the system. An implementation of the actions is directly on the system by *the actuators* [2].

Relations between main units of mechatronic device: *the system*, *the sensors*, *the actuators* and *the information processing* are connected by flows. Generally, there are three types of flows [2]:

- material flow,
- energy flow,
- information flow.

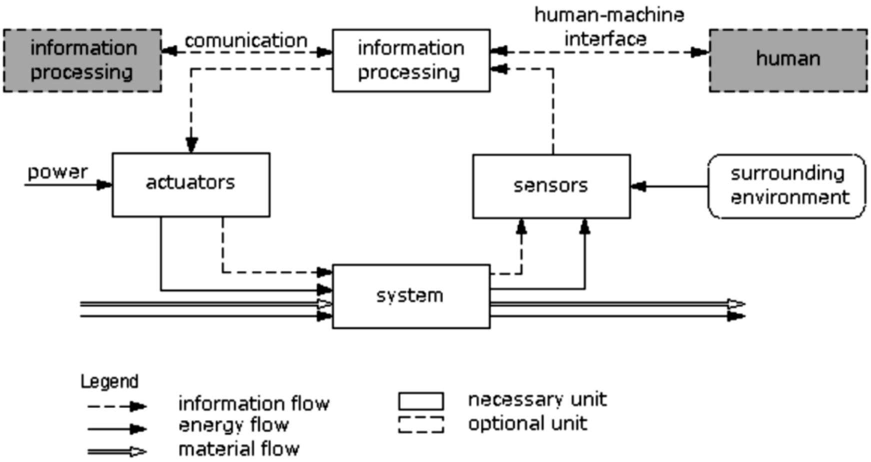

Fig. 1.2. The main structure of mechatronic system [2]

Examples of material flow between mechatronic system units are solid bodies, tested objects, processed objects, gases or liquids.

Energy flow is a different form of energy, for example mechanical, thermal or electrical but also action variables (e.g. force or current).

Information flow means the information transferred between the units of the mechatronic system, for example measured variables, pulse control or data.

1.1.2. DESIGN METHODOLOGY ACCORDING TO THE VDI 2206

The Association of German Engineers (VDI) in 2004 published the design methodology for mechatronic systems VDI 2206 [14]. The purpose of this guideline is to support the development of mechatronic products using a methodical approach. The VDI 2206 describes a flexible model, which can be used for the development of the product. The general workflow in VDI 2206 guideline is presented by the V-Model (Fig. 1.3) and can be described in the following stages:

- the main, initial model of mechatronic system is divided into modules (subsystems) with top-down direction, modules are decomposed into assemblies to obtain components like single parts (bottom level of system's structure),

- the behaviour of the system is predicted using simulation,
- bottom-up integration process with validation and verification of every level is used to obtain the main properly-defined mechatronic system (top level of structure).

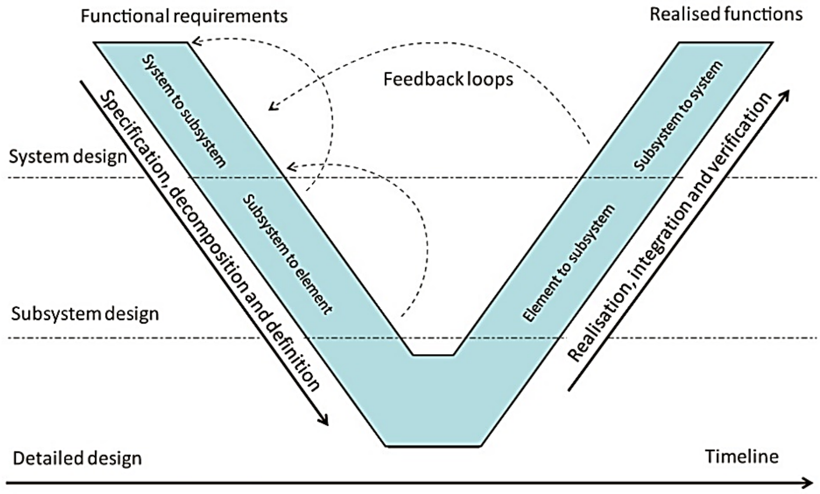

Fig. 1.3. V-model for mechatronics systems design [17]

Stages of mechatronic task solution [4]:

- problem definition of system (task to perform),
- determination of the functional structure,
- division into independent modules (subsystems),
- division of each module into the single-part structure,
- determination of the possible solution for each module,
- choose the best solution for subsystems,
- collect and/or manufacture of the components,
- integration of the components,
- functional testing of the prototype,
- documentation and presentation of the result.

1.2. MCAD POSSIBILITIES

CAx environment in mechanical engineering gives the possibility of designing a 3D virtual model (CAD) and then performing series of numerical simulations like strength analysis or flow and heat transfer (CAE), development of the technology (CAM) and creation of 2D drafting [12]. Computer-aided design however, is only a tool in the hands of engineers, therefore it is important to choose or elaborate suitable strategies for the creation of a virtual model of real objects [11]. We can distinguish various types of models such as solid, surface, hybrid (surface-solid) and multibody. Usage of these techniques depends on the complexity of the project and its purpose.

Multibody modelling technique expands the opportunities for part module and speeds up editing and possible modification of the project [3]. In single part file, we can create and adjust bodies with irregular, complicated shapes and then save them as multibody part. This kind of operation minimizes errors resulting from incorrect modelling when creating individual parts and also improves assembly stage [5].

Usage of hybrid techniques gives us possibility to create various difficult surfaces and then recreate them into solid object for proper analysis.

Complex shapes and construction of modern mechatronic solutions require the use of advanced modelling techniques based on multibody modelling combined with hybrid modelling. These techniques significantly affect the acceleration and accuracy of the design process.

1.3. MCAD AND ECAD COLLABORATION

Nowadays, CAx systems enable bi-directional collaboration between electrical (E-team) and mechanical (M-team) teams. For example, most commercial CAx systems use the ProSTEP protocol based on XML to PCB (Printed Circuit Board) design. It is an independent format that allows communication between ECAD and MCAD tools [18]. Platform for communication should allow error-free changes using only digital data. Collaboration between specialists working on the same project is carried out using PDM or PLM (Product Lifecycle Management) software dedicated for specific CAx environment. General structure of CAx tool levels and connection with IT is shown in Fig. 1.4.

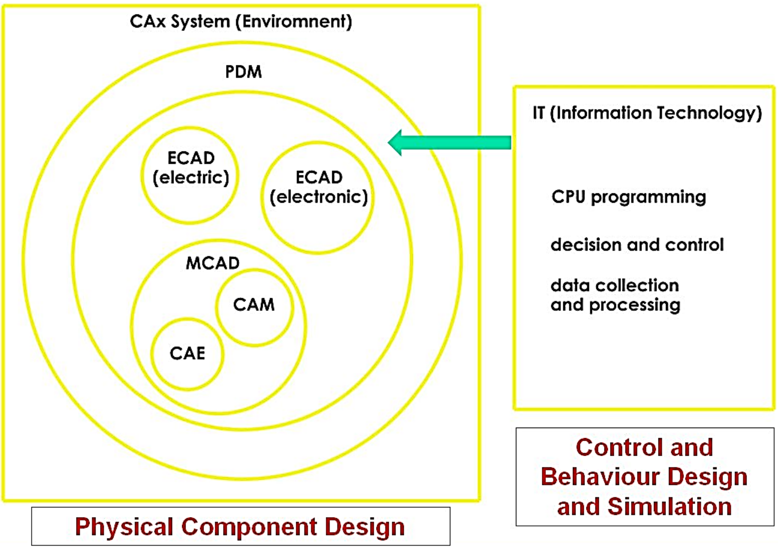

Fig. 1.4. General structure of CAx system and IT environment

Example of CAx system that use bi-directional collaboration between E-team and M-team is SolidWorks environment. Fig. 1.5 presents MCAD and ECAD tools in this CAx system. Different ECAD tools for electronic design (SolidWorks PCB) and for electric design (SolidWorks Electrical) [19] are shown here.

Electronics design solution (SolidWorks PCB) provides PCB design technology with an integrated electro-mechanical collaboration solution. It has two modules [20]:

- PCB schematics (electrical components library, schematic symbols, wiring), 2D,
- PCB layout (board shape, placement electronics components, routing of electrical traces, generate 3D electronics parts) 2D and 3D, ECAD to MCAD.

The M-team will try to mount or attach the PCB to the mechanical assembly. If the PCB does not fit perfectly with the M-design, the M-team can suggest or make some mechanical changes or modifications to the existing PCB layout. Next, push these changes back to the E-team. Example of designed PCB is shown in Fig. 1.6.

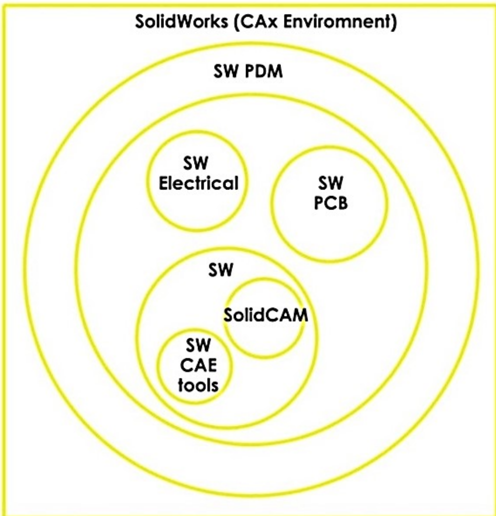

Fig. 1.5. MCAD and ECAD tools in SolidWorks environment

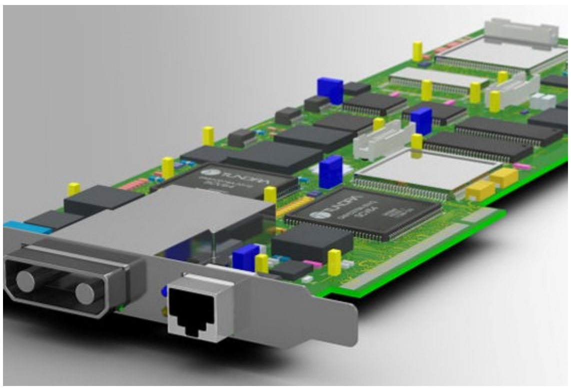

Fig. 1.6. PCB designed in ECAD (electronics design solution) [18]

Electrical 3D software (SolidWorks Electrical) enables users to convert 2D electrical system to 3D electrical system that includes: enclosure design, general arrangement, power systems, connectors, wires and cable routing and wire harness (Fig. 1.7). Capabilities include [20]:

- easy and correct placement of components,
- wire and cable length calculation,
- auto route functionality,
- create 3D general arrangement drawings based on the electrical schematic,
- harness development.

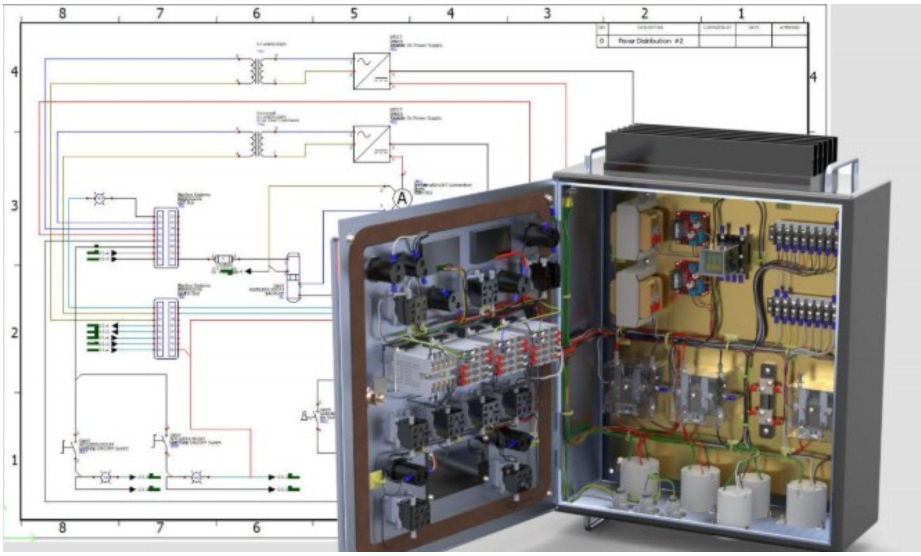

Fig. 1.7. Product designed in ECAD (electrical design solution) and MCAD [21]

1.4. CONCLUSIONS

Multidisciplinary nature of mechatronic systems enables flexible cooperation of many specialists from various industries. New methods of mechatronics systems design should include the security of product data and proper division of tasks in the team. Nowadays, it is necessary to teach both MCAD and ECAD tools in the field of mechatronics, as well as electronics and mechanical engineering.

Advanced modelling techniques minimize the possibility of errors in the early stages of design. Combining the above-described techniques provide us with an opportunity to create more advanced project in much less time than using traditional techniques. Multibody modeling used during assembly stage reduce number of parts involved in the operation tree, significantly affecting the acceleration and accuracy of the design process.

Development of data interchange protocols between MCAD and ECAD modules in CAx environment should take into account the possibility of saving data in neutral format. Team communication and cooperation rules should be defined if team uses PDM. CAx tools must be compatible across engineering disciplines.

The information technology revolution, wireless communication, MEMS technology, development of multidisciplinary approaches allow the creation of new mechatronics solutions.

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