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Up-to-date approach to design of mechatronic systems

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Abstract: *Rapid development of software tools for modeling and simulation along with the implementation of new technological achievements in engineering require a new approach to design of mechatronic systems. The paper presents modern approaches to design in mechatronics which are based on the application of software for three-dimensional modeling and simulation. It also shows the methods of designing an industrial robot according to constraint-based modeling and model-based design. Special attention is paid to the importance of developing a simulation CAD model of the robot, the integration of mechanical, electrical and software components in the process of developing the model of mechatronic systems and automatic generation of control algorithms.*

Keywords: *mechatronics; modeling; simulation, robot*

1. INTRODUCTION

Design of mechatronic systems implies a complex approach in the research work, the use of modern software tools for modeling the system elements, the integration of elements in a single mechatronic systems, modeling and simulation of the system, integration of the model, testing and verification. Due to multidisciplinary nature of mechatronics, development and design of mechatronic systems is a very complex process. There are different approaches to the design of mechatronic systems. Isermann [1] shows the development of methods of designing mechatronic systems with special reference to V model. The scheme of this model includes the distribution of tasks among the hydraulic, pneumatic, mechanical and electronic components. The method involves modeling and simulation of system components, system prototyping, testing the system parameters and their adjustment, signal analysis, creation of algorithms, system programming and testing. For theoretical and physical modeling and simulation of heterogeneous components, the following software tools are used: DYMOLA, MODELICA, MOBILE, VHDL-AMS, 20 SIM, MATLAB/SIMULINK.

2. DESIGN OF MECHATRONIC SYSTEMS

2.1. Constraint-based modelling approach

Mechatronic systems present the integration of mechanical, electrical, electronic and software components. Design of mechanical components demands the knowledge of

mechanics, machine parts and elements, kinematics and dynamics, fluid technology,friction computation, determination of the force, moment of inertia,and torque. Electronics includes measuring systems, sensors, actuators and control systems. Information sciencecomprises the application of software packages and information and communication technology for the design, modelling and integration of mechatronic systems. Design of mechatronic systems requires the integration of mechanical and electrical access so the feedback on implemented modifications is automatically receivedduring the entire process of designing. Each modification of the machine part leads to a change in the electrical system and vice versa, so there are various constraintsin the design of mechatronic systems. This approach is known as constraint-based modelling approach. Detailed analysis of this approach is shown in [2]. Design of mechatronic systemswith regard to constraints is similar to semantic networks, where constraintsand connections can be represented as nodes and relationships, respectively. The components of mechatronic systems are modelled as objects with attributes whilemutual constraints are identified and modelled. The relationship of object constraints between mechanical and electrical components at the level of concept design is shown in Fig. 1.

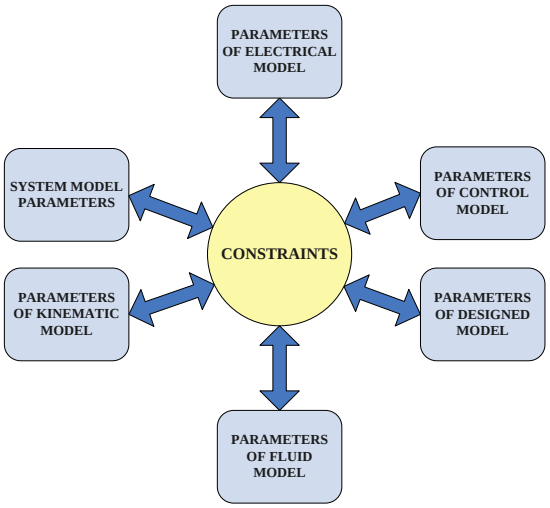

Figure 1. *Constraints among all domains at the level of concept design*

Different mechanical and electrical CAD tools are used to model, simulate and test components. Software package EPLAN Electric is often used to create electric models while Solid Works is usually used to model machine parts and elements. In the process of modeling it is necessary to take MCAD/ECAD constraints into account. Atypical approach to design and development of mechatronic systems is shown in Fig. 2.The first phase includes the analysis of technological requirements, research and definition of necessary specifications. Designers of different profiles independently make selection of necessary electrical and mechanical components, develop algorithms and create programs. The process of research and definition of specifications is largely separated by areas of research. The next phase involves design and implementation of defined model of mechatronic system. The integration and testing of the mechatronic system are done in the final phase [3].

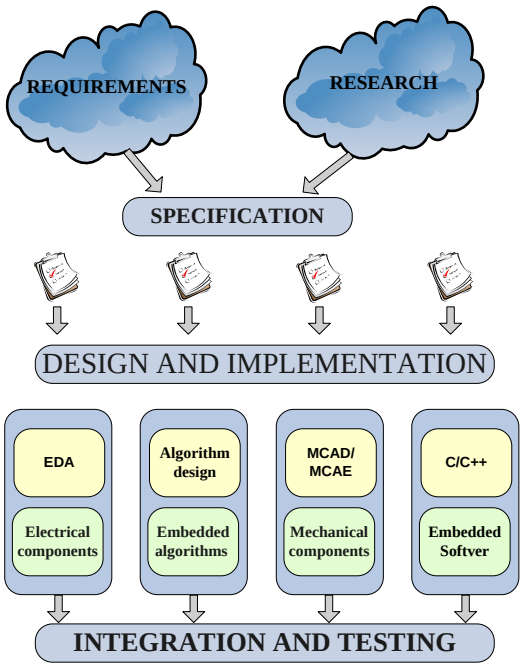

Figure 2.*Traditional process of designing a mechatronic system [2]*

The method is based on constraint modeling and consists of the following phases:

1. Creation of the list of all elements of the mechatronic system with their attributes and classification of elements into the mechanical or electrical domain,
2. Making connections between the constraints of mechatronic components within the domain on the basis of the component attributes,
3. Making connections of the elements constraints between mechanical and electrical domains,
4. Creation of the table of constraints of the mechatronic system which contains all elements of the mechatronic system and connections between constraints of the system elements.

The process of constraint modeling was created on the model of industrial robot Mitsubishi RV2AJ which is a part of the laboratory equipment in the Engineering School in Trstenik. The robot is 'vertical' with five degrees of freedom and maximum load of 2 kg. The working tool of the robot is a pneumatic handle. Figure 3 shows the constraint modeling of the industrial robot Mitsubishi RV2AJ. Mechanical, electrical, and mutual constraints are indicated by symbols M1-M9, E1-E10, and C1-C6, respectively. Mechanical constraints include geometric dimensions of the elements, base coordinates, reference coordinates of other elements, link lengths, range of link motion, type and characteristics of materials, moment of inertia, gravitational acceleration and the like. Constraints in the electrical domain include the type of engine, maximum speed, maximum load moment, encoder resolution, type of controller, power to servomotor and solenoid valve. Multidisciplinary constraints define the connections between mechanical links, joints and engine, maximum torque, force, maximum load, range of motion, control of robot tools, and the like. The constraints being defined, the size, dimensions, power, speed and control mode of the engine are selected.

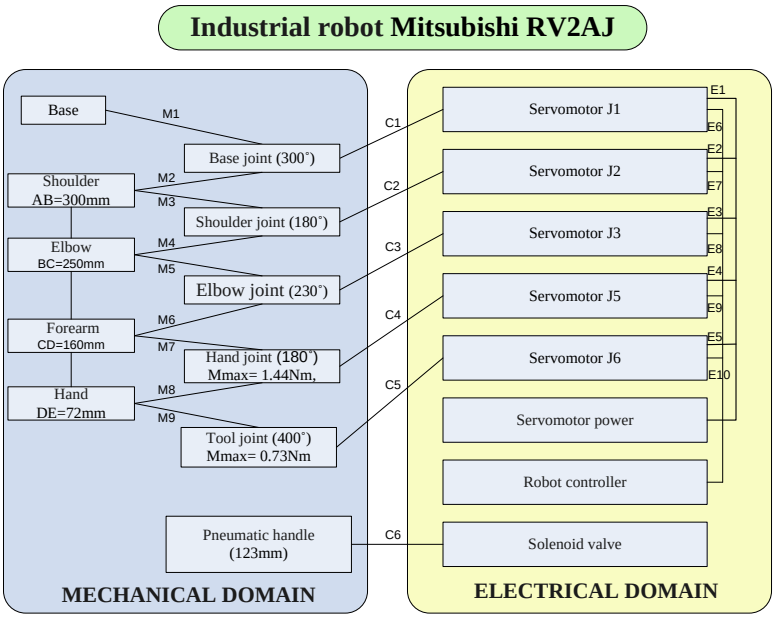

Figure 3.*Constraint modeling of Mitsubishi RV2AJ*

The process of designing is mostly done separately so the feedback on the changes of components is late whereas the testing of integrated system is done at the end of the process. This approach has the following constraints:

- Complex analysis and complex procedure of changes,
- Misinterpretation of requirements,
- Complex system of project integration,
- Incomplete and expensive system,
- Testing cannot be done by levels of development,
- Lengthy process of error detection,
- Limited transportability,
- Limited monitoring from design phase to integration phase.

2.2. Model-based design

Up-to-date multidisciplinary approach to design of mechatronic systems is based on integrated development environment which enables creation, modelling and testing of mechatronic systems. Today's trends in the design of mechatronic systems are based on the system modelling, three-dimensional modelling, simulation and implementation of the model in real industrial systems. Festo company has developed a control system based on MATLAB and Simulik for model-based desing, model implementation of the model in programmable logic controller (PLC) using Simulink PLC Coder [4].

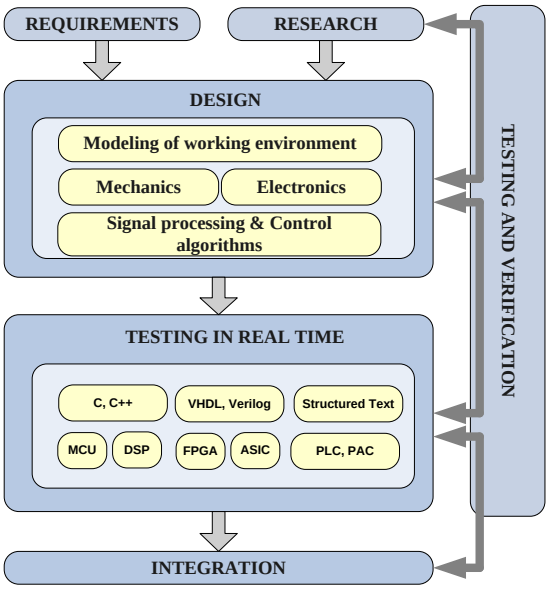

Figure 4.*Modern approach to design of the mechatronic system – Model-based design [3]*

This approach provides the model simulation, code generation for PLC programming in the same programming environment. Procedure of model-based design is shown in Fig. 4. Based on defined requirements and constraints,we research and design the simulation CAD model of the robot which generates SimMechanics model (XML file). Modelling of electrical and mechanical assemblies, signal processing and creation of control algorithms are integrated in the design phase. After creatingall models, we simulate the model in MathWorks software package, test the model and generatethe control STL code for the PLC using Simulink PLC Coder [5]. The system parameters are tested and verified during the entire process. A change of any element or parameter automatically leads to a change of other parameters so that thesystem maintains designed characteristics. This approach enables multidisciplinary cooperation over the entire process of design in real-time, as well as testing, verification and validation ofthe model in all phases of the project, thus reducing the time and cost of developing new systems and improving the product quality.

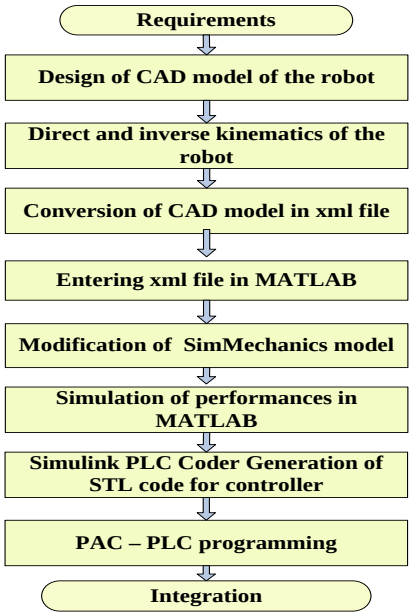

Figure 5. *Algorithm of model-based design of the mechatronic system*

The algorithm of design of the industrial robot is shown in Figure 5. Integration of the system is done after its testing and verification.

3. CONCLUSION

The paper presents the current trends in the design of mechatronic systems. Modern software tools are applied to design the model of industrial robot. Special attention is paid to the specific qualities of mechatronic approach to design, analysis mechanical and electrical of constraints, and their integration into a single mechatronic system. Application of up-to-date software packages enables fast and safe way in the development and design of new mechatronics components and systems.

REFERENCES

[1] Isermann, R. (2007). *Mechatronic systems: Innovative products with embedded control*, Control Engineering Practice, doi:10.1016/j.conengprac.2007.03.010.

[2] Kenway, C., Jonathan, B., Jitesh, P., Dirk, S. (2009). *A Framework for Integrated Design of Mechatronic Systems*, Collaborative Design and Planning for Digital Manufacturing, pp. 37-70, Springerlink.

[3] Jack, L. (2014). *The Impact of Model-Based Design on Controls Today and in the Future*, MathWorks.

[4] Rüdiger, N. (2014). *Festo Develops Innovative Robotic Arm Using Model-Based Design*, Festo.

[5] http://www.mathworks.com/products/datasheets/pdf/simulink-plc-coder.pdf