

# Complex technical systems modelling and their mechatronics function simulation

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**Abstract.** One of the elements of designing complex technical systems is the problem of their various aspects of designing and modelling. In the field of design, the issues of both system design and material design should be considered which aspects would fit the given function of the given system. Each complex mechatronic system is defined as a combination of three component subsystems, namely a mechanical system, a control system and software. In this context, it is important to create a mechatronic function of such a complex technical means using tools that allow it to be modelled. In the article is presented a method of integrative approach as well as its formalization in the form of integration of different construction characteristics that should be optimized. The paper includes the example of its application for developing the construction of this support. The support is a special design of a mining machine intended to support the roof over that area of hard coal mining. In the paper is also described the results of the characteristics analysis and changings that were introduced afterwards. The support models are prepared in the computer environment of the CAD class. Also the analyses were conducted in this design, graphical environment.

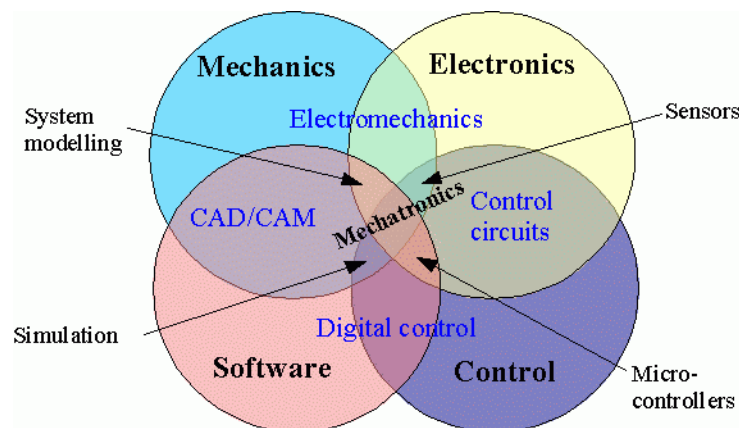
## 1. Introduction

The most innovative and heuristic stage in the process of new product development is the designing one. This stage requires an intelligent and synthetic approach what was in the past reserved for designers. There was no possibility for computer aiding of such kind of tasks. It was visible not only during mechanical design process but in the same manner for other areas of designing and particularly for the architectural design process. The most important factor in this design process was experience of the design team members. Nowadays this problem is of particular importance because of changes in the philosophy of designed objects. It has been elaborated the concept of mechatronics devices what influenced the change of the designing process [1,2].

Generally, mechatronics is a new technology combining mechanics, electronics, computers and new information technologies as well as communication (during wide world web leading to the Internet of Things [3]) what is presented in figure 1. Cooperation of these different areas allows thinking differently about the product from conception to recycling including its maintenance. Mechatronics is aimed to create components and solutions more and more intelligent for meet the requirements of particular and individual customers. This is why during mechatronic device designing it is somehow



needed to work simultaneously in every technology and to have a general picture of things. Mechatronics devices allow improving men's safety, allowing automatic shutdown machines in the event of a failure. It improves power efficiency of controlled machines, providing more flexible operation. It promotes also the respect for the environment by improvement device's durability. If failures are detected before the device could take the required action to prevent the damages. It allows to meet specific client needs and to achieve personalized solutions.

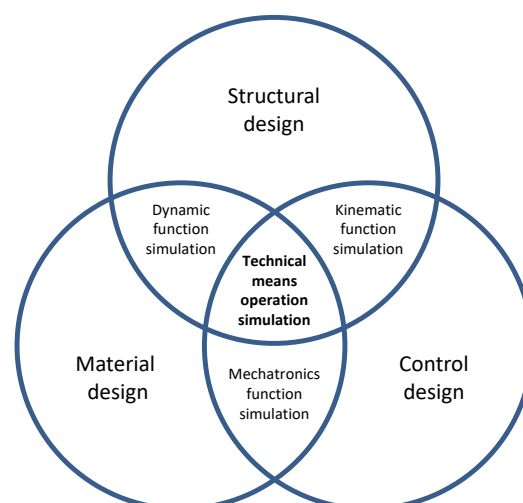


**Figure 1.** Mechatronics as a system [4].

The presented structure of a mechatronics system could be the base for analysing the integrative approach in designing new technical solutions of such complexity level. The mentioned analysis is presented in the next chapter.

## 2. Theory of design complex systems

Designing of complex technical means is dependent on the previously determined structure of its system. Basing on experience and theoretical analysis [5] it was determined that such a system is a synergetic composition of three main subsystems and its sets of attributes. Hence a designing process should be treated as simultaneous one. It should link three sub-processes of designing (figure 2). The correctness of individual solutions is validated using a simulation approach. It could be determined three simulation tests of three single functions of a technical means.



**Figure 2.** Virtual simulations of a technical mean.

The individual simulation investigations are related with the process of verifying the results of designing of particular two subsystems of a technical means. Taking into consideration the presented diagram it could be determined the next three simulation processes:

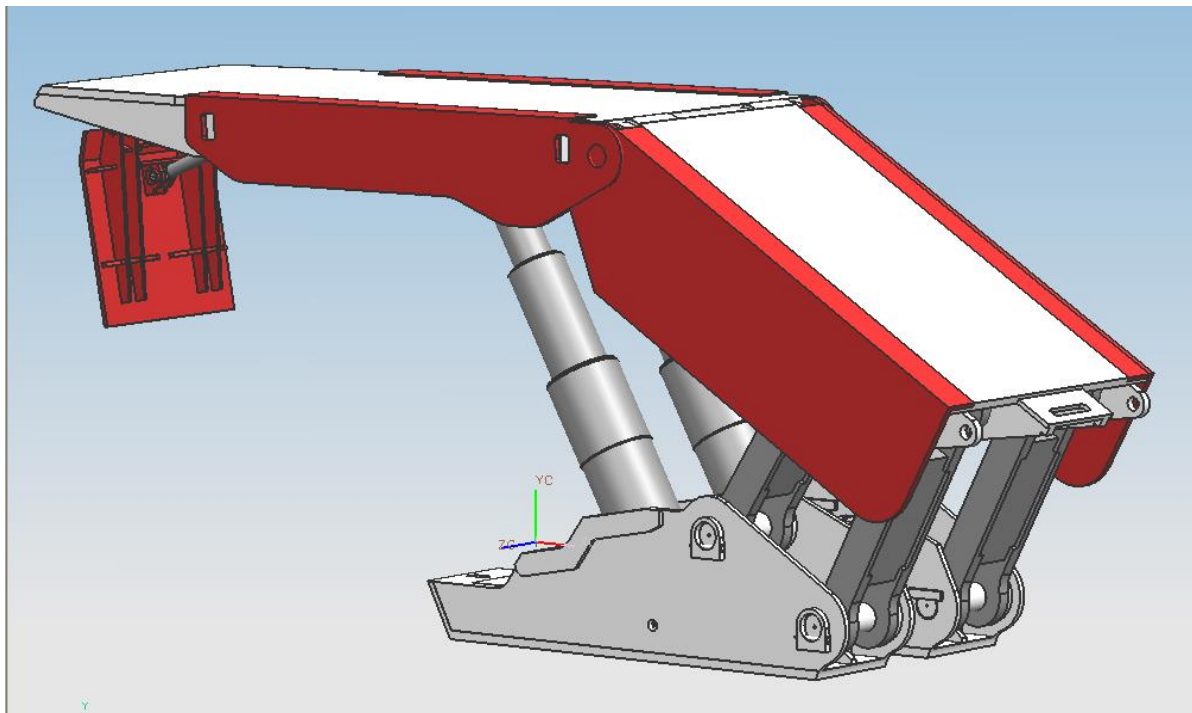
- kinematic function simulation,
- dynamic function simulation,
- mechatronics function simulation.

The first one allows determining the correctness of motion of the analysed complex technical means. It is possible to conduct it in almost all CAE environments. This analysis let to determine velocities and accelerations of chosen points. The next one concerns the problem of strength analysis of complex designs. It allows determining the forces and moments (generalized loads) loading the structural part of a construction as well as the mechanical parameters of drives. The last one is a new one. The mechatronics function simulation is a process of verification the correctness of operation the control program taking into consideration the control program and material parameters influencing the control procedure. The analysis of the last one is presented in this work

### 3. Mechanical complex systems design

The mechanized mining support is a machine designed to protect the mining area against roof rocks falling. Among other problems one of the important one is the problem of support material characteristics. Nowadays are conducted works related with introducing new type of materials [6].

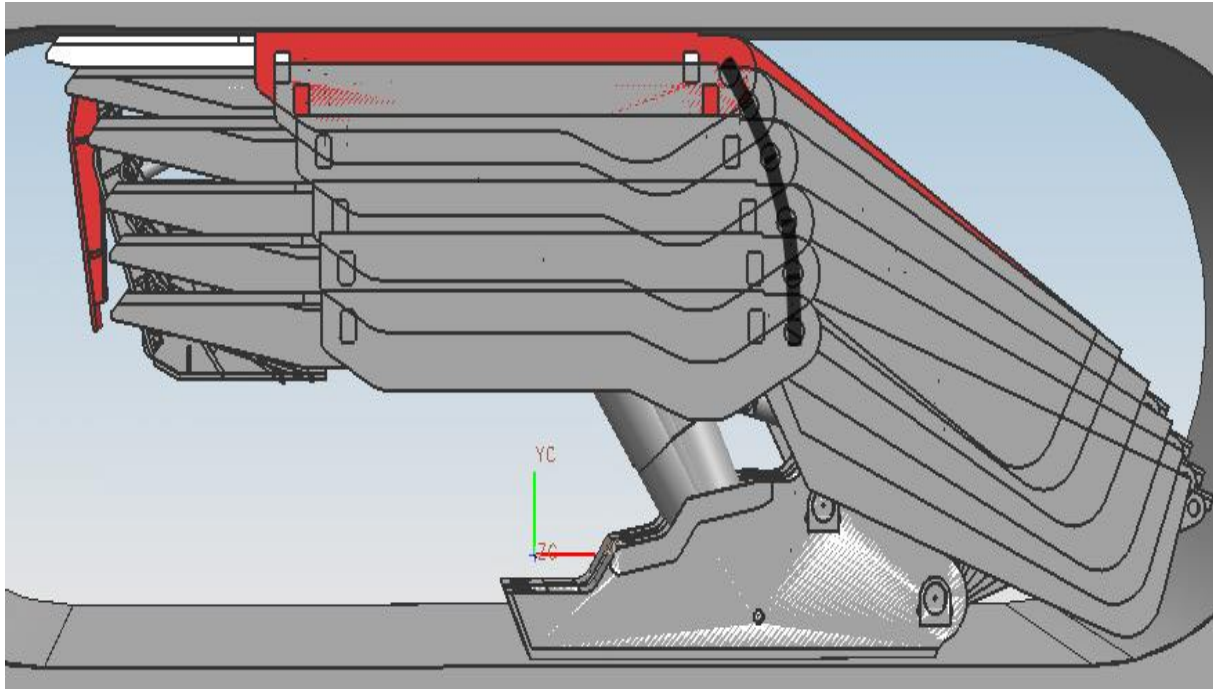
Typical mechanized mining support consists of some main subsystems. In figure 1 are presented the structural subsystem and the drive one excluding the hydraulic power system in a form of a virtual model. The model was elaborated in a CAD/CAM/CAE design environment.



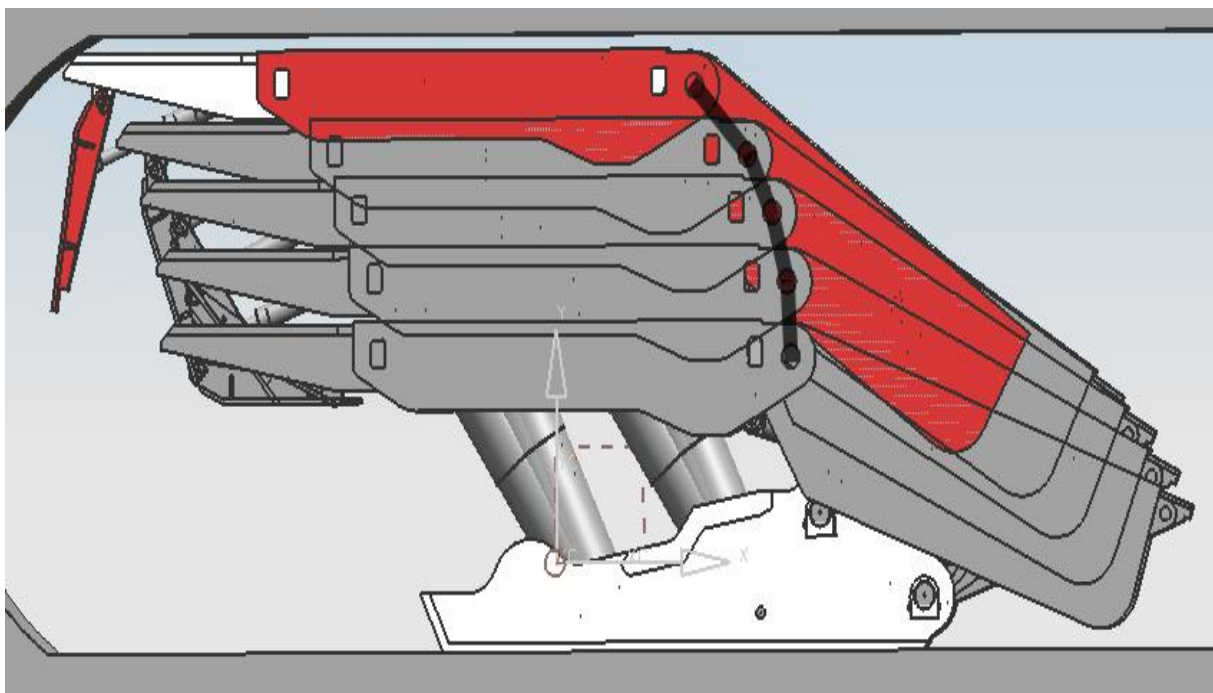
**Figure 3.** Virtual model of a mining support.

To conduct investigations of analysed class of technical means (mechanized mining supports) it was elaborated the control program. Normally the control system of a support is designed as an electro-hydraulic one. For the purpose of this analysis it was modelled in the system. Using this developed model, the investigations have been conducted. In figures 4 and 5 are presented the analysis of two and four props support operation in the contact with the roof. These two types of a support belong to

the most widespread one. More than 80% of supports belong to this type. Their disadvantage is a horizontal shift during operation in a contact with a roof. It generates harmful forces which could cause the damage of a support or at least shortening of its durability. This is why it is important to analyse its mechatronic function. The four props support, in contrary to the two props one characterizes with more uniform distribution of stresses.

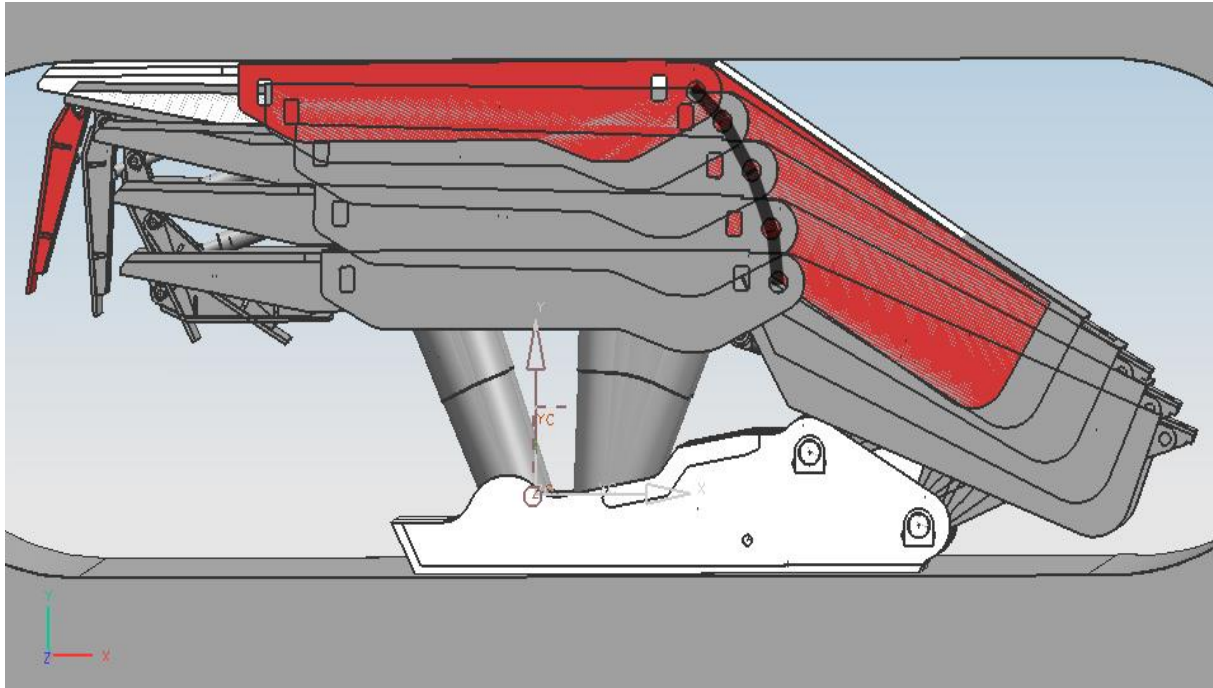


**Figure 4.** Mechatronic function analysis for the two-props support.

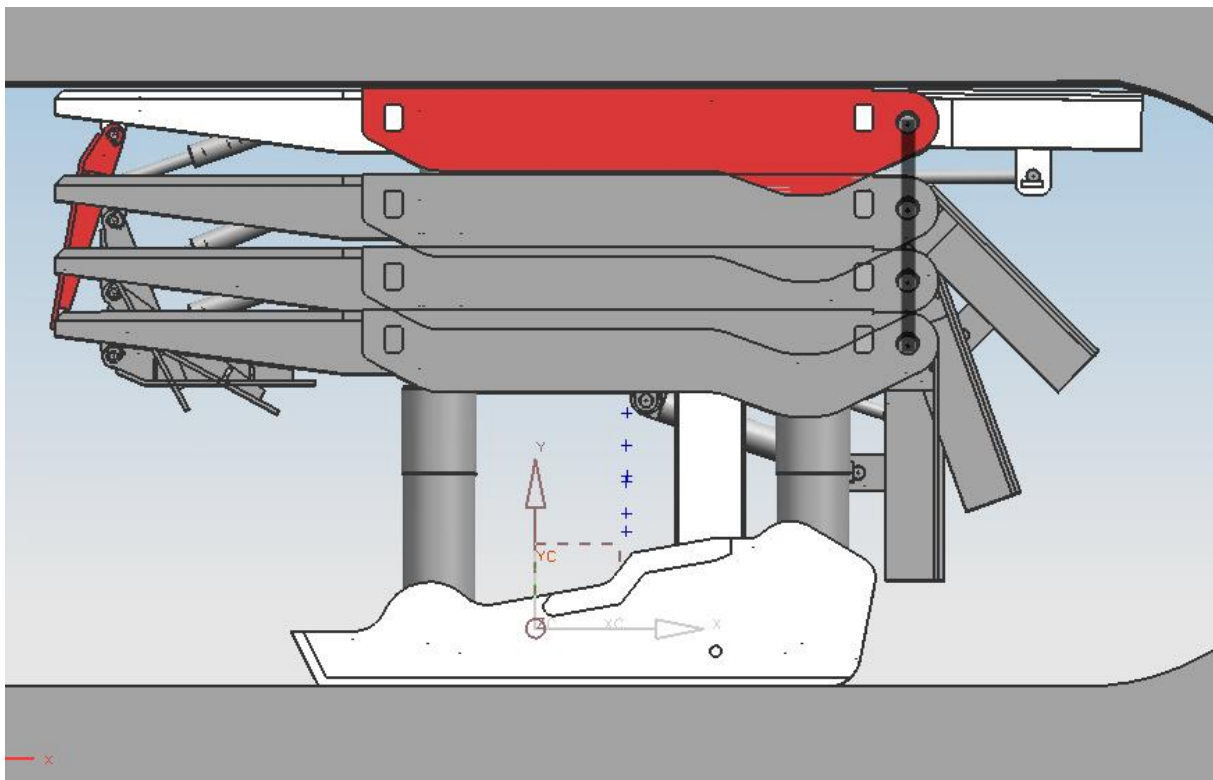


**Figure 5.** Mechatronic function analysis for the four-props support.

Below are presented results of analysis for more rare support types. The V-shape support was designated to transfer the load on stable mounted props (figure 6). However, the straight-line support was designed to eliminate the skew motion of the canopy (figure 7).



**Figure 6.** Mechatronic function analysis for the V-type support.



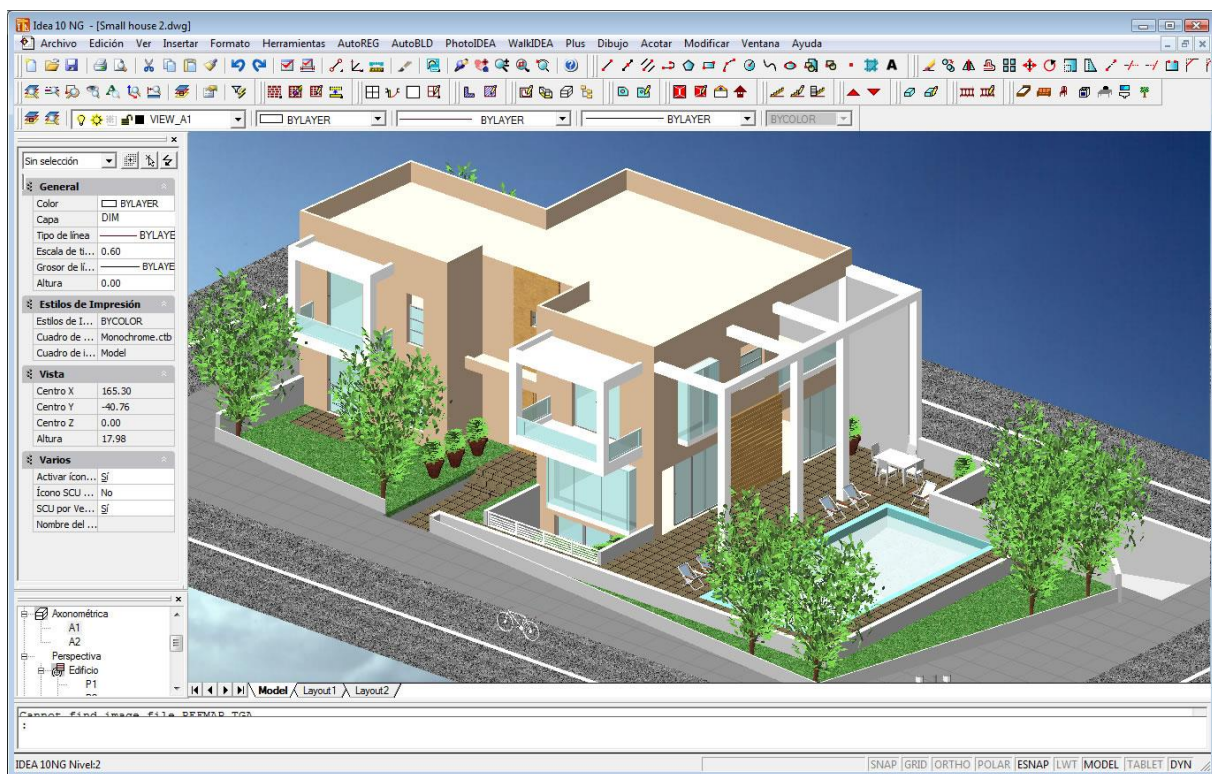
**Figure 7.** Mechatronic function analysis for the straight-line support.



The conducted investigations allowed determining the control program of operation of a support during its contact with the roof as well as tuning its work parameters and construction attributes. It shows that in the case of mechanical projects it is easy to conduct the analysis of mechatronics function in advanced CAD/CAE environments basing on properly elaborated 3D models.

#### 4. Architectural complex systems design

The presented above approach could be applied also in other engineering areas. Particularly difficult is the application of this approach in the area of architecture [7]. The house designs nowadays are very complicated, particularly when including its “drive” - energetic and control subsystems. In figure 8 is presented exemplar 3D model of a detached house.



**Figure 8.** Virtual model of a detached house [8].

To analyse the mechatronic functions, it is needed to determine and model the energetic and control functions of such type of a composed technical means. Sometimes it could be valuable to use the rapid prototyping tool [9]. Contemporary building could be treated as very complicated mechatronics system including the structural subsystem, the energetic one as well as the control one. The last is the most complex being responsible for the functioning of the building, for ensuring proper life conditions and the energetic balance of all energetic systems of the building as well as environment balance of the whole structure.

Works are conducted now to analyse the mechatronic function of the security subsystems basing on the control of sensors, locks and roller blinds. One of steps is a try to build virtual model together with a real model to compare the functioning of the analysed area of the building mechatronics function.

#### 5. Conclusions

In the presented paper is discussed the problem of mechatronic function analysis. The mechatronic function is a term for describing the operation of the control system of a technical means basing on a specific attribute that is the control program. The control program as the system attribute refers to the

program itself as well as to settings of control devices and their functioning characteristics being the result of their “material” attributes (such as type of VLSI devices, actuators characteristics, drive properties, sensors behaviour, etc.) influencing their work functions [10].

Developing the complex system designing is it important to elaborate the software approach of all three subsystems creating a technical means. It is very problematic in the case of material function however extensive researches in this area are conducted [11, 12].

In the case of mechanical system, the analysis of mechanical technical means the modelling analysis of the mechatronic functions is in a sense more predictable. The variety of devices representing the control system as well as their work range are partially limited with their operation function or the set of operation function as it was shown on the case of mining supports [13]. However, for the buildings, being technical solutions of more complex systems determining and modelling their mechatronics function became more difficult task. Of course in this case more proper would be the term *buildtronics* and analysis of the *buildtronics* functions. This is the direction of the future works that are planned to conduct to improve this type of technical means designing.

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