

MODELING OF MECHATRONIC SYSTEMS IN MATLAB (SIMULINK / SIMMECHANICS)

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ABSTRACT

Article reviews the training manual “Modeling of mechatronic systems in MATLAB (SIMULINK / SIMMECHANICS)”, which demonstrates the approach to the modeling of mechanical systems using the SimMechanics/Simulink/MATLAB environment. The article describes the structure of training manual and the main stages learning of design and analysis of mechanisms that are found on the basic knowledge of students from courses of university. Thus, the described in the textbook examples of the analysis of mechanisms using SimMechanics library helps to perpetuate the previously learned knowledge. The paper given special attention to the psychological aspects of students' perception of educational and methodical material, learning is based on the principle "from simple to complex" and follows the ideas of visibility and interaction of sensory perception of reality and intellectual knowledge. Tutorial Examples contained in the article and offered to students for learning based on the principles of modern technical devices, which helps to establish the relationship between theoretical knowledge and practical experience.

Keywords:

simulation, MATLAB, SimMechanics, analysis of mechanisms, kinematics of mechanisms, dynamics mechanisms, training manual

1. INTRODUCTION

One of the most effective systems of software for numerical computations in the present days is MATLAB - matrix laboratory and high level programming language. To increase the functionality of the system, there is a Simulink library - supplement provides block imitating modeling of various systems and devices with the use of modern technology a visual-oriented programming. In Simulink toolbox in addition to general there are specialized packages for solving a specific purpose tasks, for example, SimPowerSystems - for modeling energy systems and devices, Signal Processing - for modeling signal processing systems,

Fuzzy Logic - for the simulation of fuzzy systems and others (Li, et al., 2013).

For modeling systems and devices of the physical nature of greatest interest is the Simscape package. In this package there are blocks that represent physical bodies interacting by means reactions, as opposed to block Simulink, which are mathematical operators and interact with each other by means signals. Simscape includes such sections as SimElectronics - for the simulation of electronic and electromechanical systems, SimHydraulics - for the simulation of hydraulic systems, SimMechanics - for the simulation of mechanical systems.

Implementation of the MATLAB in the learning process of many universities is rapidly and there is a lot of literature on this topic. However, there are special packages are described in sufficient detail to fully understand. Therefore especially important to create educational materials for the study of special package tools covering a certain direction of science and technology.

In recent years the Department of Mechatronics, Saint Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO University) in the educational process and scientific research is widely used package SimMechanics. In packet-based testing, is a method of comparing the results of a particular physical model with its analogue and analytical conclusions on the degree of its approximation. On the basis of experience gained during the modeling of mechanical systems, it was decided to create a tutorial for students and teachers.

2. THE STRUCTURE OF THE TRAINING MANUAL

Figure 1 shows the structure of training manual in graphical form. It consists of four training chapters, each chapter has a section dedicated to the theoretical information, detailed solutions examples (3-4 pcs.), as well as tasks for students self-study. There are about 12 completing example and more than 50 self-study tasks.

Theoretical information in the chapters intended for reference purposes as soon as textbook designed for senior baccalaureate courses and magistracy. To help the student there is extensive list of references.

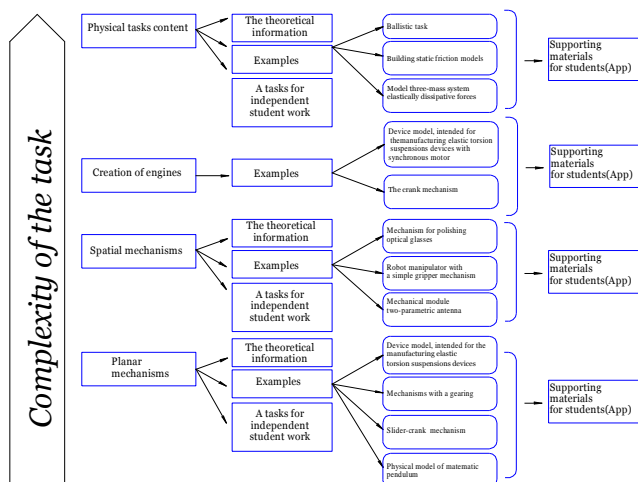


Figure 1. The structure of the training manual "Modeling of mechatronic systems in the MATLAB (Simulink / SimMechanics)»

Task complexity increases gradually from chapter to chapter. However, each set of tasks based on previously studied material, and individual case studies consistently included in tasks that are more complex. It allowing students to retain new knowledge, due to repeated repetition of material. Case Studies gradually disassembled setting, all used blocks, and control programs are given in the annexes. Therefore, the students can successfully carry out the training on their own. Perform tasks for self-study requires maximum use of the knowledge gained. A similar sequence presentation of material allows to control the learning process and to evaluate student's knowledge level adequately.

3. MODELING OF MECHANISMS

The first example is for modeling the physical model of a simple pendulum shown in Figure 2 and 3. It is one of the simplest systems for modeling and allows students to get acquainted with the SimMechanics blocks and their interaction with each other.

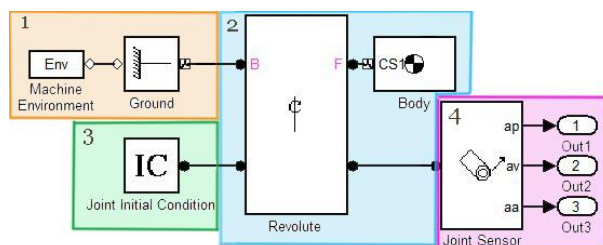


Figure 2. Structural model of a mathematical pendulum in SimMechanics

Modeling and research of pendulums with various modifications is an important task, because the vibrational elements are working bodies in many

measuring devices. For example, in the sources (Kot, et al., 2013; Li, et al., 2013; Dyakonov, 2005; Dyakonov, 2008) by different authors there are models of these pendulums.

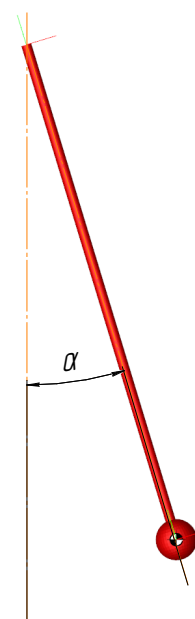


Figure 3. The output - SimMechanics animated model of the mathematical pendulum

Further, the level of complexity of models gradually increased. The following example is a slider-crank mechanism, two-stage gearbox and the weaving devices actuator model designed for the manufacture of elastic torsion suspensions, Fig. 4 and 5 (Musalimov, et al., 2013; Perechesova, 2012; Zamoruev et al., 2012; Kalapyshina, 2012).

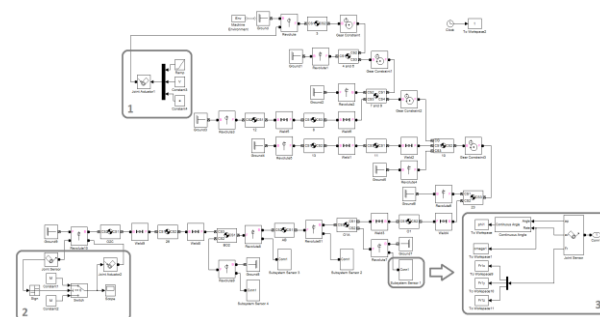


Figure 4. Structural model of the weaving device actuator in SimMechanics

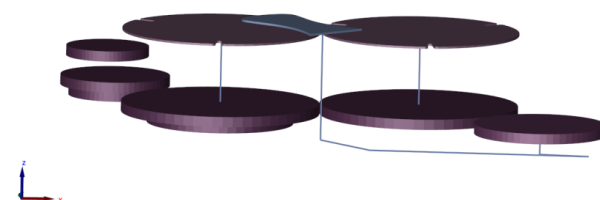


Figure 5. The output SimMechanics - animated model of the weaving device actuator

Model actuator plaiting together the knowledge of students about the work SimMechanics blocks designed to simulate planar mechanisms. It includes all of the subsystems previously discussed, or their equivalent. Value model for learning is that there is a mechanism used in the Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation, Russian Academy of Sciences, St. Petersburg Department (SPbF IZMIRAN).

Sections tasks for independent works devoted to flat mechanisms are based on the mechanisms that invented and investigated by P.L.Chebyshev, and also on the training devices mockups, existing at the Department of Mechatronics ITMO (Fig. 6) (Musalimov, et al., 2013). Such an approach allows the ideas of visualization and helps to establish the relationship the sensory perception understanding of reality and intellectual knowledge. Figure 7 shows an example of a student's independent work, which aims to draw a parallel between the real object and the model in MATLAB.



Figure 6. Study mock of devices, laboratory of the Department of Mechatronics ITMO University;

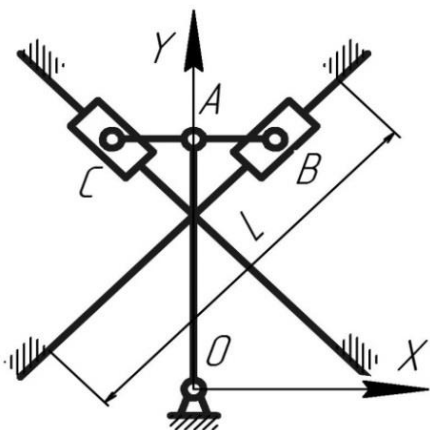


Figure 6. The tasks for independent work of students and Structural model of a student's SimMechanics

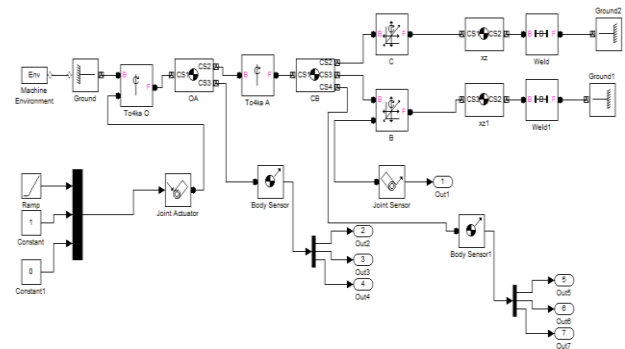
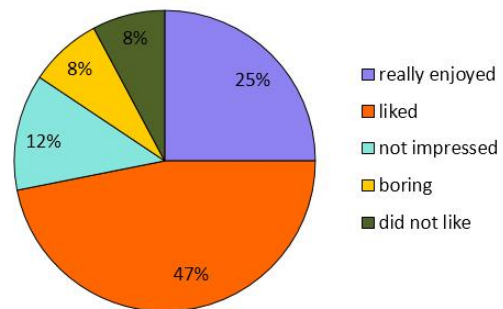


Figure 7. The Structural model of a student's SimMechanics

Opinion survey was conducted among undergraduate students of 4 training groups totaling 64 people. Investigated emotional perceptions and complexity of discipline. Results of the survey are shown in the diagrams (fig.8). It would be concluded a successful testing of course.

Emotional perception of the course by students



The course complexity of students' opinion

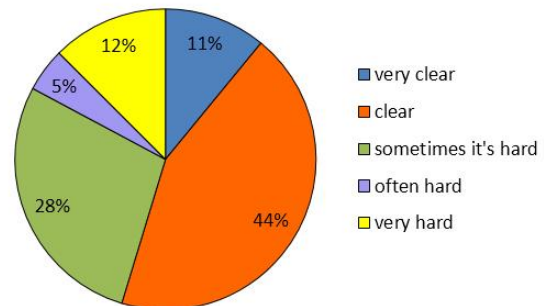


Figure 8. The result of students' opinion survey

Further development of the educational process requires a sequential increase of complexity of the tasks at the same time bringing them closer to the actual mechanisms that are used in modern industry. As a fifth example, students are supposed to analyze and model the mechanical part of a two-parameter antenna (Musalimov, et al., 2013; Perechesova, 2012). As a mechanics object the system under consideration is a representative device with parallel kinematics. His movement occurs in two planes. A sixth example is an actuator for processing of optical elements (Kalapyshina, 2012). The most obvious in this section is an example of modeling the robot with the capture of Fig. 9.

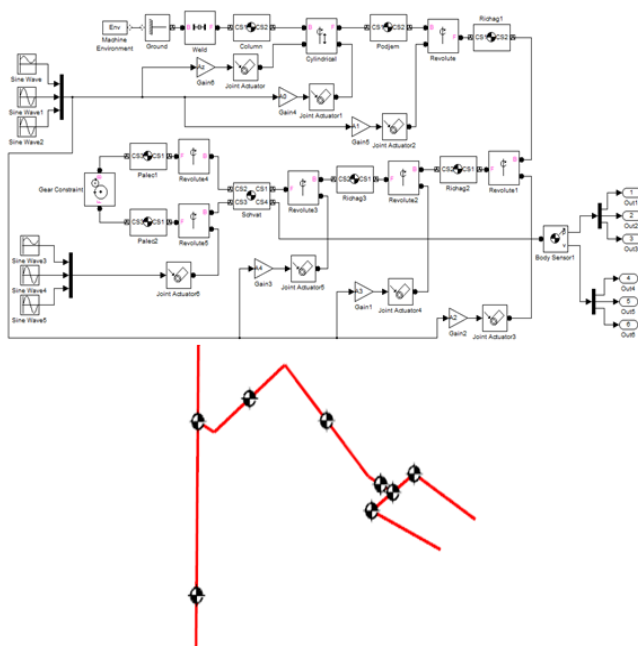


Figure 9. Structural model of the robot with SimMechanics capture and result of - Animated SimMechanics model robot with capture

Robotics is the most actual for the modern industry. Therefore, many research organizations and universities are conduct the research in this area. Examples of modeling of robots-manipulators are described in (Zimmermann, et al., 2009) and in (Xiao, et al., 2009; Rybak, et al., 2013; Ghanbari, et al., 2013; Hasan, et al., 2009) are studies of the mechanisms using the SimMechanics.

In the training manual, also designed section dedicated to solving problems of complicated physical and mathematical laws, the presence of external influences, resistance forces, the presence of higher kinematic pairs (Musalimov, et al., 2013). This section is offered to educate the problem of the three bodies interaction, associated elastic-dissipative forces, static friction model and ballistic task. A good example is SimMechanics model for solving the problem of ballistic Fig. 10 and 11.

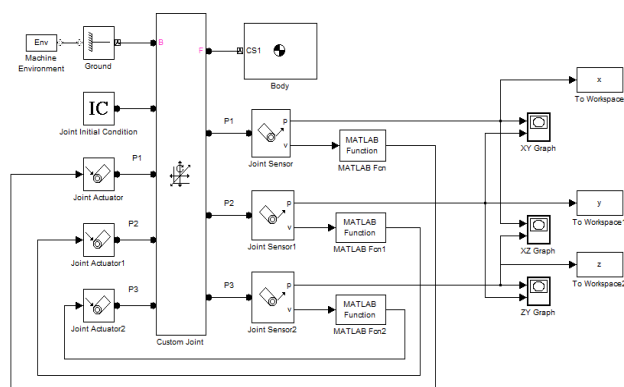


Figure 10. Structural model SimMechanics for ballistic problem

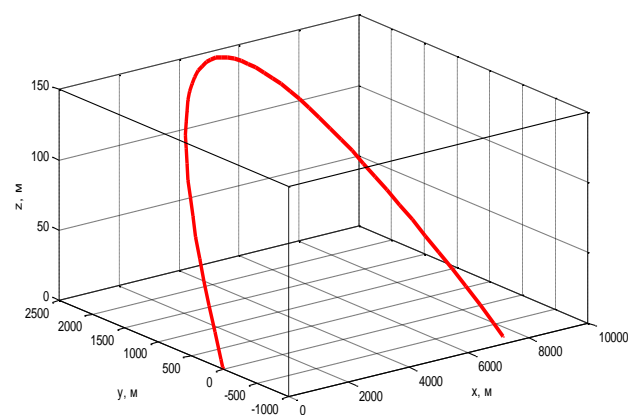


Figure 11. Result - the solving the ballistic problem

The last section of a manual, is dedicated to creating engines. It prepares students for further education of MATLAB SimMechanics library, package Simulink and others.

4. CONCLUSION

Described in the textbook fundamentals of the theory of machines and mechanisms and theoretical mechanics and methods of mathematical modelling of various mechanical systems and physical processes. The manual provides models of mechanisms, mechanical and measuring systems made using the library SimMechanics, package Simulink environment MATLAB. The appendices contain the necessary data for playback students models. To sections of the job AIDS designed for self-study.

The manual is recommended as a textbook for masters of higher educational institutions, enrolled in the direction of masters preparation 200100 "Instrument-making" and the 221000 "mechatronics and robotics", may be useful for students studying courses "Theory of mechanisms and machines", "Designing of mechatronic devices", "Fundamentals of designing and design of devices for use in the master's programs "System simulation in mechatronics", "Modular technology in biomechatronic and robotics", as well as for teachers and researchers dealing with the issues of the course "Theory of mechanisms and machines". The textbook was given the stamp of UMO "Instrument making" resolution 588 from 29.11.2013, For the development of the educational process perspective direction is the creation of electronic educational-methodical complex UMK), simulation of mechatronic systems in the MATLAB/Simulink/SimMechanics, for distance learning AcademicNT, developed in St. Petersburg national research University of information technologies, mechanics and optics (UNIVERSITY ITMO). This system allows to increase the efficiency and quality of teaching, the unified structure of electronic educational and methodological resources and the use of modern computer technologies.

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Participant of International conferences and congresses (Denmark, Poland, Italy, UK, Germany, Portugal, Romania, Russia etc.).

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G.B. Zamoruev. Graduated in 1962, specialty - Marine machinery. He worked as a design engineer in the turbine building of the ships. Since 1966, he began teaching at the Leningrad Polytechnic Institute at the Department of Theory of mechanisms and machines. In 1972 he defended his thesis. In 1976 he was promoted to the rank of associate professor and to the corresponding post. In 1980 he moved to Leningrad Institute of Fine Mechanics and Optics at the Department of Theory of mechanisms and instruments parts (hereinafter Department of Mechatronics, ITMO University) as an associated professor, where I work now.

At the moment, my overall experience is 52 years old, of which teaching at higher educational institutions - 48 years (the last 34 at ITMO University) .

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- kinematics and dynamics of mechanisms (including robotic manipulators);
- simulation of mechanisms, systems and processes;
- methods and computer programs for optimization modeling.

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I.I. Kalapyshina. Graduated the Mechatronics department at the University of Information Technologies in 2010. Since this time has been phd-student of the same department. From the 2012 has been working as assistant in Mechatronics department. Number of published scientific works is about fifteen.

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