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ScienceDirect

Procedia Engineering 129 (2015) 362 – 368

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Industrial Engineering

# Formal method to design a macro-model of a transport vehicle mechanical system translational motion

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**Abstract**

The article is devoted to the formalization [1] of the design of mathematical model for the computer simulation of complex mechanical systems. The simulation object is the mechanical system of the transport vehicle (railway or automotive). The complete system is split into subsystems (macro-elements), each of macro-element has one degree of freedom. The whole system of macro-elements can be considered as a translational moving system. A two-stage algorithm to construct a mathematical macro-model of the transport vehicle mechanical system - is presented. The results of the computer simulation are presented. This modeling method is beneficial to be used in the educational process to establish interdisciplinary connections, as well as to create e-learning resources for students of applied mathematics, information technology and engineering profiles.


Peer-review under responsibility of the organizing committee of the International Conference on Industrial Engineering (ICIE-2015)

*Keywords:* Computer simulation; complex mechanical system; vehicle; formal method; object-oriented approach; e-leaning.

## 1. Introduction

One of the significant areas of research in the field of solving the problems of modeling through the use of modern computer technologies is a computer simulation of complex mechanical systems.

It should be noted that at present, particular significance is the formalization of mathematical models of systems and processes in the context of solving specific practical problems, due in no small measure to solving of the urgent problem of import substitution in the field of software systems CAD/CAM/CAE. A very important problem is the

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Peer-review under responsibility of the organizing committee of the International Conference on Industrial Engineering (ICIE-2015)
doi:10.1016/j.proeng.2015.12.079

problem of teaching students to create new, including specialized software systems that support the functions of mathematical modeling complex mechanical systems [2-11].

The problem of modeling the dynamics of mechanical systems of vehicles [1,4-9] is a good example of the object of research in teaching students the principles of computer simulation [10, 11]. This task allows student to have the intuitive interpretation of system parameters. Intuitive interpretation also corresponds to results, which are presented in the form of dependency graphs from the time the motion. From a practical point of view, to the area of the considered mechanical systems are included trains and railway crews, and it includes means of road (automotive) transport, including vehicles of auto truck transport.

## 2. The ways to modeling of mechanical systems

Due to the practical importance of a problem, currently the considerable number of works is devoted to creation of adequate mathematical model of mechanical systems of transport vehicles and their computer realization. In particular, for several years the design of the relevant modules of software system "Universal Mechanism" (UM) is developing under the supervising of prof. Pogorelov D.Y. [5, 6, 12, 13]. However, it should be noted that the study of models and methods [5-9, 12, 13] for implementation of mathematical software of software complex UM [14] is a separate task that requires a good mathematical training and deep knowledge in the subject area. This task is beyond the base curriculum for computer simulation training course for the bachelor studying, for which mechanical transport systems are not the main and only object to study.

As a different approach to the construction of mathematical models of complex mechanical systems process can be used formal methods based on the principles of the existence of the Electro-mechanical analogy and on the using of "global" variables, objects, and elements of circuitry [15, 16]. An example of such approach is the use of simulation technology of mechanical systems by means of a formal language and a graphical representation of the modeled mechanical system using similar electronic circuits in accordance with international standard VHDL-AMS.

However, in order to establish interdisciplinary connections in the learning process more rational approach may be the use of the method of generalized energy phase variables (GEPV) proposed in [10] for the design of mathematical models within CAD systems. The topology of the system in this method can be represented as in the form of the electrical circuit analog electronic devices and as in the classic form of a directed graph. The implementation steps of this method are based on mathematical and formal tools of the disciplines of applied mathematics. Objects for modeling by method GEPV can be discrete dynamical systems and sub-systems of different physical nature. It is worth noting that the GEPV analogy of phase variables, of topological and of component equations for different physical systems are consistent with the standard VHDL-AMS in which the corresponding phase variables appear with the names "across quantity" and "through quantity". The construction of mathematical models of complex mechanical systems can be carried out using classical methods of theoretical mechanics [2-4] with the use of modern technology implementation in an object-oriented approach also. Object-oriented approach is widely used now to solve different mathematical and specialized problems [17-20] by means of simulation by tools of object-oriented programming technology.

Method GEPV and object-oriented approach at the correct introduction of the parameters of the system elements allows to construct a mathematical model which fully corresponds [1, 4] to the model obtained by mathematical tools of theoretical mechanics. It should be noted that when modeling systems consisting of the solids that perform various types of mechanical motion, the basic method GEPV [10] require to design of a complex system of circuits and the imposition of laws of interrelation variables based from the subject area.

## 3. Two-stage method to modeling of mechanical systems of transport vehicle

As discussed in [1], for use in the educational process rationally [20] integrated application of methods of classical mechanics with GEPV method. When using the proposed technology the resulting system to describe the in relation to each other of movement of macro-elements in the direction of the main (target) movement can be seen as performing translational mechanical movement that corresponds to one of five basic types of physical subsystems, adequately simulated by the method GEPV [4]. Under the proposed approach, the macro system, shown in left part of figure 1, means to split the system into interconnected subsystems, each of which is characterized by separate