Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 45 ISSUE 1 March 2011

Computer-aided analysis and synthesis of branched mechanical systems

K. Białas*
Institute of Engineering Processes Automation and Integrated Manufacturing, Faculty of Mechanical Engineering, Systems, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: katarzyna.bialas@polsl.pl

Received 11.01.2011; published in revised form 01.03.2011

Analysis and modelling

ABSTRACT

Purpose: The main aim is to present and describe the author's program supporting the process of analysis and synthesis of discrete vibrating mechanical systems with branched structures. Synthesis of reference concerns the reverse problem and is aimed to obtain the structure and parameters of the system that meets the previously established requirements for the values of vibrations frequencies.
Design/methodology/approach: Using the program presented in this paper, it is possible to carry out the synthesis that is understood as designing of the systems. The use of such non-classical method significantly reduces designing time compared to classical methods. An important advantage of the program is a lack of need for the formulation of new mathematical models used to describe the system, with the change of its parameters or structure. The program also facilitates comparison of the passive and active vibration reduction.
Findings: The presented software allows comparison of the results of the use of passive and active elements of vibration reduction of the systems under consideration. The analysis shows that active elements reduce the vibration completely and passive elements reduce the vibrations only partially.
Research limitations/implications: The scope of considerations is limited to discrete longitudinal vibrating mechanical systems with branched structures containing passive or active elements for reduction of vibrations.
Practical implications: The presented methods of synthesis and analysis can be useful for designers and engineers in the design and construction of this type of mechanical systems.
Originality/value: The possibilities and operation of the author's program aiding the synthesis and analysis of discrete mechanical systems are also discussed. By means of this software it is possible to carry out the analysis and synthesis of discrete systems containing both active and passive elements that reduce vibrations.
Keywords: Process systems design; Synthesis; Reduction of vibrations

Reference to this paper should be given in the following way:
K. Białas, Computer-aided analysis and synthesis of branched mechanical systems, Journal of Achievements in Materials and Manufacturing Engineering 45/1 (2011) 39-44.

1. Introduction

The issue of vibrations reduction is very often the subject of numerous researches in many scientific centres. A reason for this is that the vibrations do exist and they are very common in our environment. The phenomenon of vibrations in the cases of some machines and equipment may be the basis of their operation (e.g., vibrating conveyors, impact hammers, and compactors), however for most of them, vibrations are undesirable and have a deleterious effect on the functioning and reliability. Therefore, the aim for designers and engineers is to counteract their effects at the design stage of new equipment and facilities [1-3].

There are various methods of vibration reduction, which can include: vibration isolation, vibration damping, and elimination thereof. These methods can be realized through the use of passive, active or semi-active elements. The application of passive elements causes a certain limitation, i.e. it is only possible to dissipate energy or store it periodically, and moreover there is no possibility to change their parameters in time. The semi-active elements apply passive components, but their value can be changed. The use of active elements allows compensation for vibrations through the vibrations from additional external sources [1,2,4,5].

This work is the author's presentation of the software for analysis and synthesis of longitudinally vibrating systems with passive and active elements for reduction of vibrations. The described program consists of two sub-programs. The sub-program named *Synthesis of Cascade Mechanical Systems* (in Polish: ***S**ynteza **K**askadowych **U**kładów **M**echanicznych - **SKUM***) is used for analysis and synthesis of cascade-connected systems, and the second sub-program is used for analysis and synthesis of systems with branched structures (*Synthesis of Mechanical Systems with Branched Structures* in Polish: ***S**ynteza **R**ozgałęzionych **U**kładów **M**echanicznych - **SRUM***) [6,7].

As a result of the program-based synthesis - the reverse problem - the structure and parameters of the system meeting the requirements for the frequency of vibration are obtained [3,6-15].

Analysis – the simple problem – consists in graphical presentation in the form of amplitudes or deflections of the system without reduction of vibrations and with the use of passive or active elements [3,7,12,16-18].

2. Description of the software operation SRUM

Description of operation and use of sub-program *Synthesis of Mechanical Systems with Branched Structures* was presented by carrying out the synthesis and analysis of branched restrained system with three degrees of freedom, which operates under a dynamic excitation to the first element of inertia.

The main selection screen appears after activation of the program, which is shown in Figure 1.

In the first step, the user indicates the number of resonance and antiresonance frequencies and selects the structure of the system (the restrained system, the semi-defined system – not restrained) in the Data (in Polish: Dane) section. Once the data on the frequency and structure are approved, the window (Figure 2) with an extension Enter the frequency (in Polish: Wprowadź częstości) appears, in which the user specifies the value of each frequency of the system.

To obtain the values of individual inertial and elastic elements as well as to see a basic drawing of the obtained system that meets the desired requirements, one should go to the section Synthesis results (in Polish: Wyniki syntezy), where one can also select the system in relation to the method of restraining (Variant 1, Variant 2, Variant 3) – Figs. 3-5.

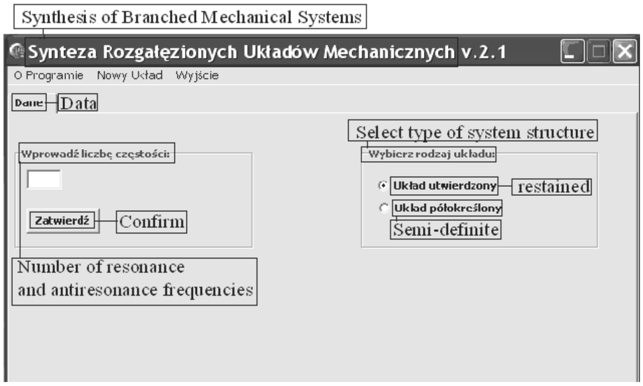

Fig. 1. The main program window

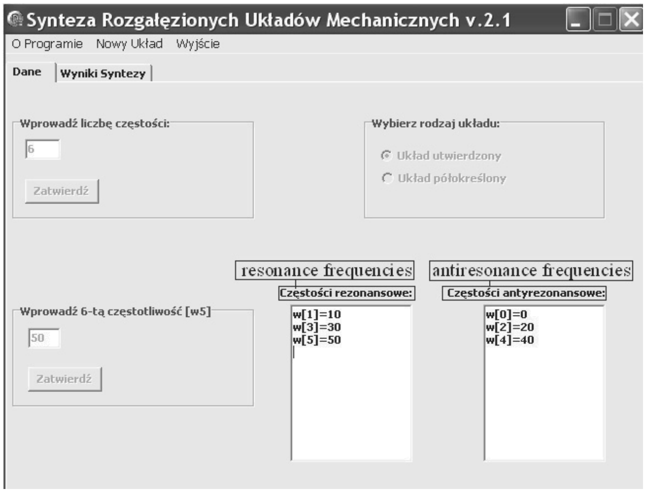

Fig. 2. Introducing frequencies

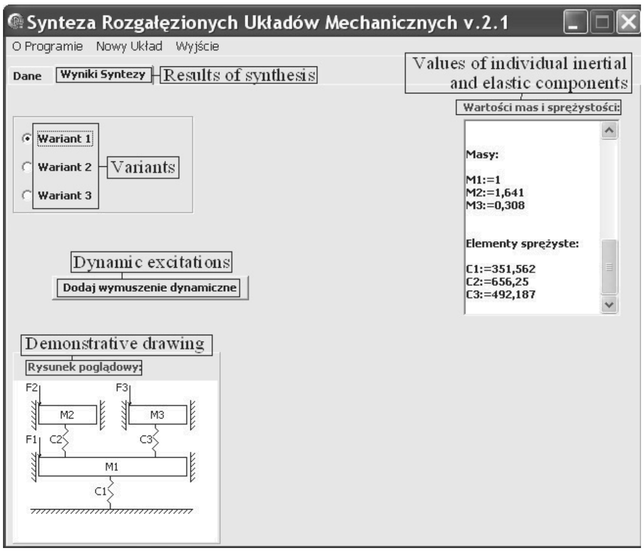

Fig. 3. Results of synthesis – variant 1

By selecting *Variant 1* (in Polish: *Wariant 1*) one receives a system in which the first inertial element is restrained; in case of *Variant 2* (in Polish: *Wariant 2*) the second inertial element is restrained and for *Option 3* (in Polish: *Wariant 3*) two inertial elements are restrained – first and last. For further consideration the system corresponding to the first Variant was chosen. In order to determine the number and value of dynamic excitations, one must select *Add a dynamic excitationn* (in Polish: *Dodaj wymuszenie dynamiczne*)in the same window – which results in opening the next window as shown in Figure 6.

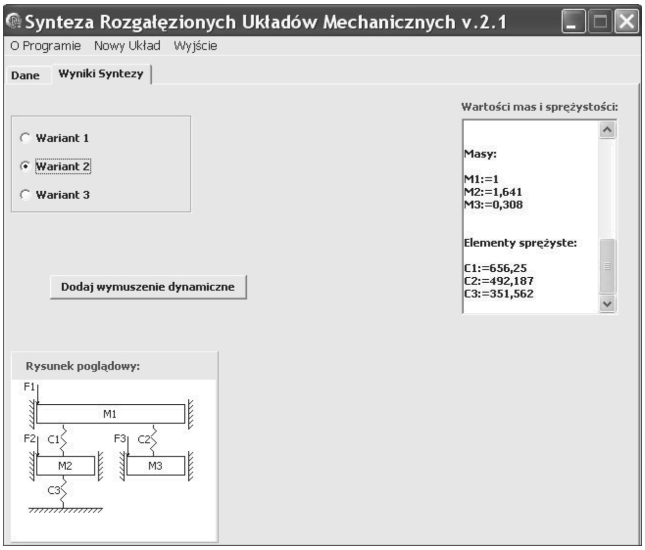

Fig. 4. Results of synthesis – variant 2

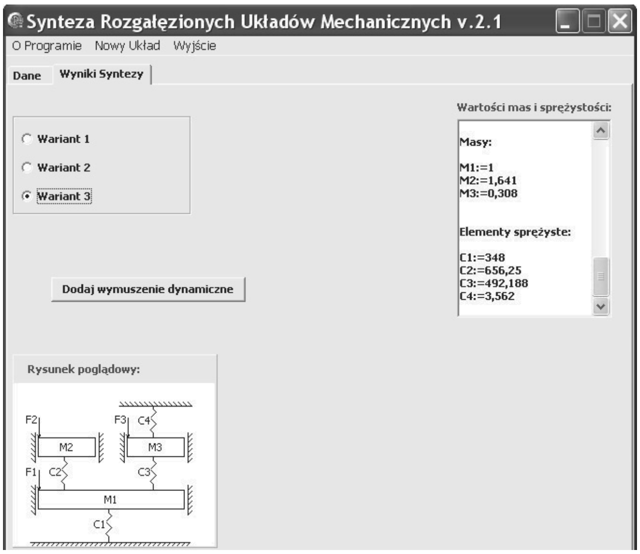

Fig. 5. Results of synthesis – variant 3

Following the introduction of dynamic excitations and their acceptance, the screen with diagrams of the amplitudes is displayed. In order to see the next diagrams, one must "move" the slider *Amplitude Index* (in Polish: *Indeks amplitudy*) (Figs. 7-9).

To add the passive or active elements to the system, which reduce vibrations, one must select *Add suppression* (in Polish: *Dodaj tłumienie*) section – visible in Figures 7-9, which will result in the program screen (Fig. 10), where one can select either passive or active suppression. In case of passive suppression, the proportionality coefficient ratio shall be taken from a defined range and accepted. A window with diagrams (*BT TP graphs* in Polish: *Wykresy BT TP*) appears, which compare the amplitudes (without suppression – black) and maximum displacement of the system (with passive suppression – blue). The present paper is limited to presenting only the comparison of the amplitude and the maximum displacement of the first inertia element. These diagrams are shown in Figure 11.

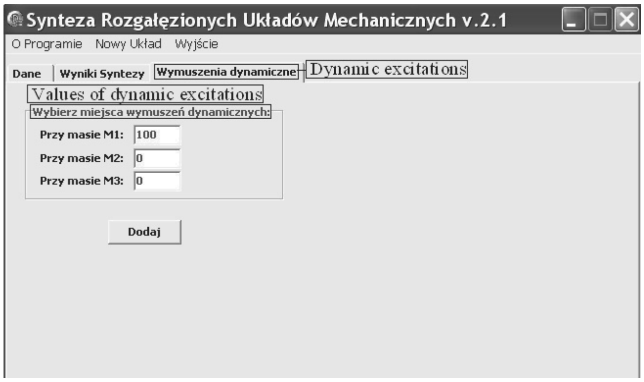

Fig. 6. Dynamic excitations

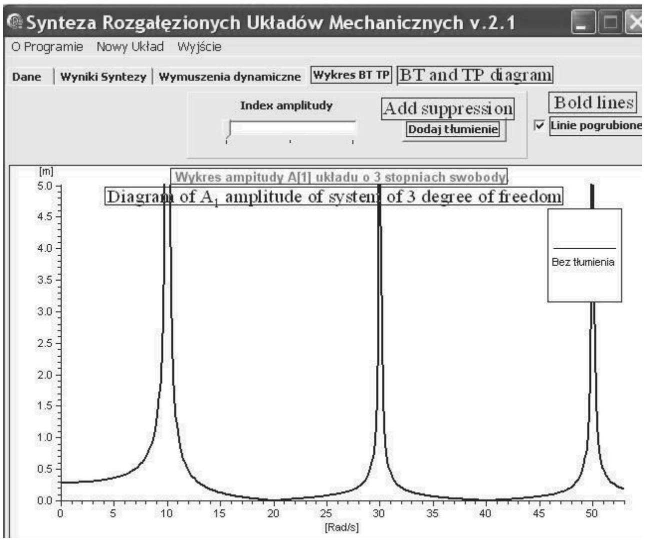

Fig. 7. Diagram of A_1 amplitude

Using this program described, it is possible to determine the values of active elements. To do this, one should go to the *Suppression* (in Polish: *Tłumienie*) section and then select *Add* *active silencers* (in Polish: *Dodaj tłumiki aktywne*) option. A dialog box (Fig. 12) appears on the screen, which shows a drawing of the basic system together with the active elements and the values of these elements at each frequency of own vibrations of the system.

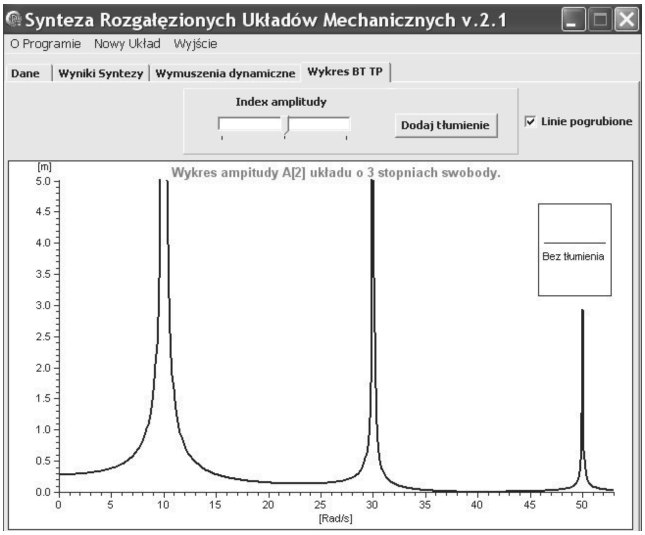

Fig. 8. Diagram of A_2 amplitude

After determining the value of active elements by selecting the *TA diagrams* (in Polish: *Wykresy TA*) section, one can see the graphic comparison of the maximum displacements of the system with the active elements (red lines) and diagrams of amplitudes without any vibrations reductions (black lines). The present paper was limited only to a comparison of the amplitude and the maximum displacement of the first inertia element at various frequencies of own vibrations of the system. These diagrams are shown in Figures 13-15.

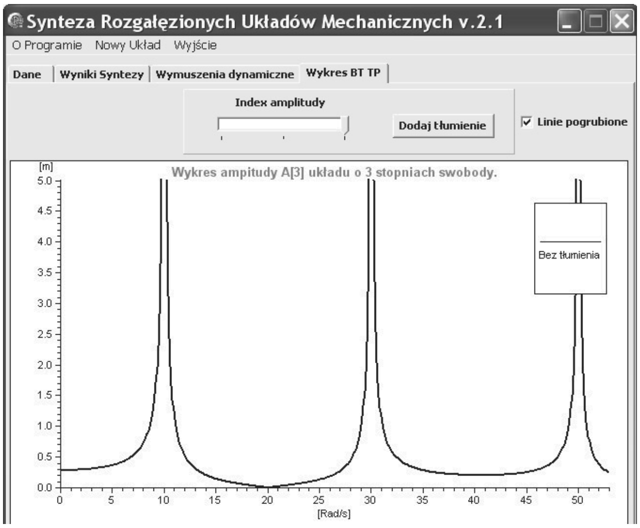

Fig. 9. Diagram of A_3 amplitude

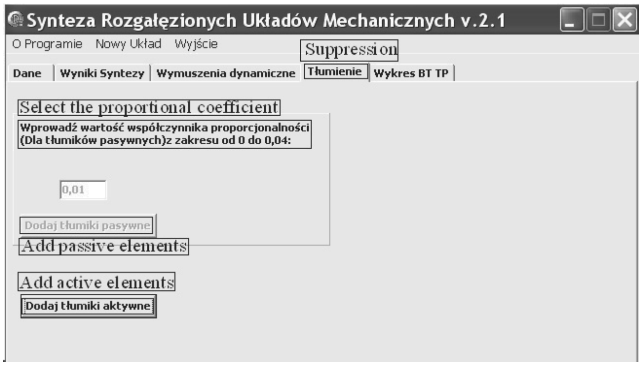

Fig. 10. The window of the damping selection

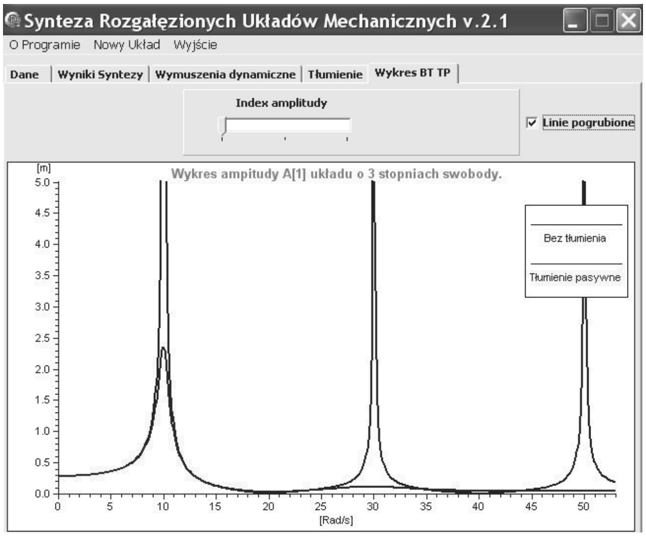

Fig. 11. Diagram of A_1 amplitude and maximum displacement

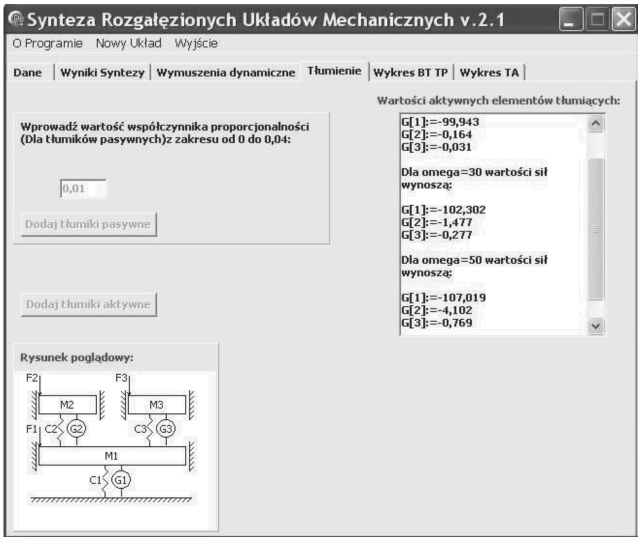

Fig. 12. Values of separate active elements

In the main menu one can choose from three functions: *About the program* (in Polish: *O programie*), *New system* (in Polish: *Nowy Układ*), and *Exit* (in Polish: *Wyjście*). Selecting the *About the program* displays a window with the program creation date and information about its author. Activating the *New system* option directs to the main initial dialog box where one can determinate the structure of the new system and the number of its frequencies. *Exit* option ends the use of the program.

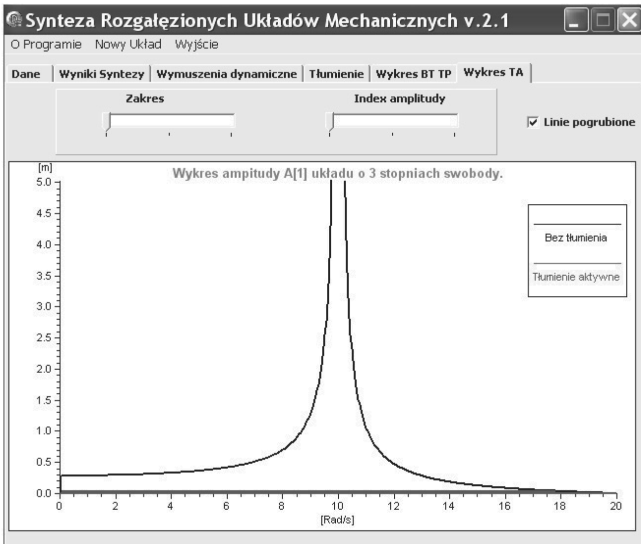

Fig. 13. Diagram of A_1 amplitude and maximum displacement of system at $\omega = 10\frac{rad}{s}$

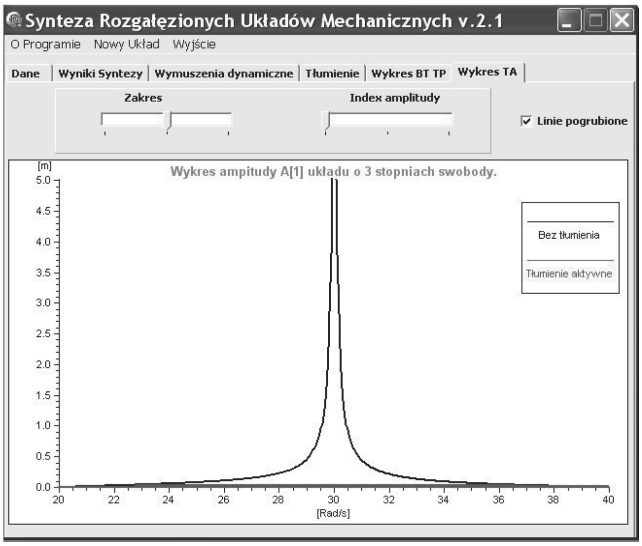

Fig. 14. Diagram of A_1 amplitude and maximum displacement of system at $\omega = 30\frac{rad}{s}$

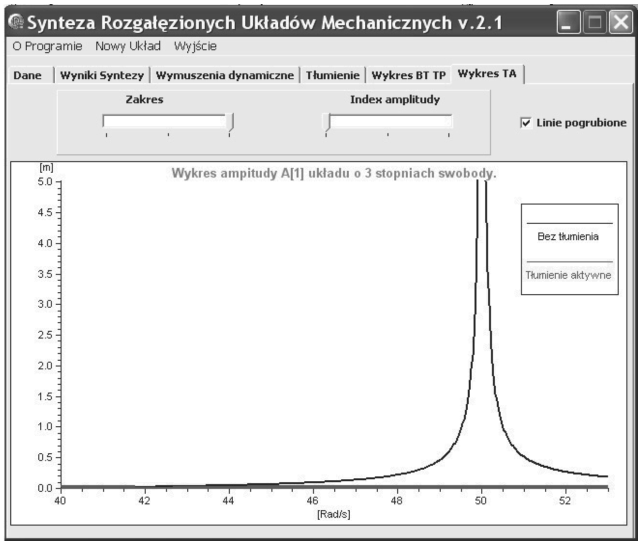

Fig. 15. Diagram of A_1 amplitude and maximum displacement of system at $\omega = 50\frac{rad}{s}$

3. Conclusions

The paper presents functions of the author's program aiding the synthesis and analysis of discrete longitudinally vibrating mechanical systems with branched structures.

Using this program it is possible to conduct synthesis, understood as designing of systems with desired properties. This program also sets the values of forces generated by active elements and defines the value of passive elements reducing vibrations.

When analyzing the diagrams in the form of amplitudes and displacements of the systems it is possible to compare the effects of passive and active methods of reduction.

The use of the program presented in this paper significantly reduces the time of execution of the synthesis and analysis. The advantage of the program is also no need to formulate mathematical models used to describe the system.

Acknowledgements

This work has been conducted as a part of the research project No. N N502 452139 supported by Polish Ministry of Scientific Research and Higher Education in 2010-2013.

References

[1] Z. Engel, J. Kowal, Vibro-accoustic processes control, AGH Press, Cracow, 1995 (in Polish).

[2] S. Michałowski, Active systems in machines construction, Monograph 171, Cracow University of Technology Press, Cracow, 1994 (in Polish).

[3] A. Buchacz, J. Świder (Eds.), Computer support CAD CAM. Support for construction of systems reducing vibration and machine noise, WNT, Warsaw, 2001 (in Polish).
[4] D. Guidaa, F. Nilvetti, C.M. Pappalardo, Parameter identification of a full-car model for active suspension design, Journal of Achievements in Materials and Manufacturing Engineering 40/2 (2010) 138-148.
[5] E. Świtoński, A. Mężyk, W. Klein, Application of smart materials in vibration control systems, Journal of Achievements in Materials and Manufacturing Engineering 24/1 (2007) 291-296.
[6] K. Białas, A. Buchacz, T. Dzitkowski, Synthesis of vibrating active mechanical systems with dumping in view of polar graphs and structural numbers, Monograph 230, Silesian University of Technology Press, Gliwice, 2009 (in Polish).
[7] K. Białas, Computer-aided synthesis and analysis of discrete mechanical systems, Journal of Achievements in Materials and Manufacturing Engineering 38/2 (2010) 171-178.
[8] A. Buchacz, K. Żurek, Reverse task of active mechanical systems depicted in form of graphs and structural numbers, Monograph 81, Silesian University of Technology Press, Gliwice, 2005 (in Polish).
[9] A. Buchacz, Investigation of flexibly vibrating subsystem of mechatronic system, Journal of Achievements in Materials and Manufacturing Engineering 34/1 (2009) 55-62.
[10] K. Białas, Reverse task of passive and active mechanical system in torsional vibrations, Journal of Achievements in Materials and Manufacturing Engineering 35/2 (2009) 129-137.
[11] K. Białas, Polar graphs and structural numbers in synthesis of active and passive mechanical systems, Journal of Achievements in Materials and Manufacturing Engineering 30/1 (2008) 43-50.
[12] K. Białas, Graphs and structural numbers in analysis and synthesis of mechanical systems, Journal of Achievements in Materials and Manufacturing Engineering 29/2 (2008) 151-154.
[13] A. Buchacz, A. Dymarek T. Dzitkowski, Design and examining sensitivity of continuous and discrete-continuous mechanical systems with required frequency spectrum represented by graphs and structural numbers, Monograph 88, Silesian University of Technology Press, Gliwice, 2005 (in Polish).
[14] A. Buchacz, The expansion of the synthesized structures of mechanical discrete systems represented by polar graphs, Journal of Materials Processing Technology 164-165 (2005) 1277-1280.
[15] A. Buchacz, Dynamical flexibility of discretecontinuous vibrating mechatronic system, Journal of Achievements in Materials and Manufacturing Engineering 28/2 (2008) 159-166.
[16] A. Buchacz, Exact and approximate analysis of mechanical and mechatronic systems, Journal of Achievements in Materials and Manufacturing Engineering 33/1 (2009) 47-52.
[17] G. Wszołek, Modelling of mechanical systems vibrations by utilisation of GRAFSIM software, Journal of Materials Processing Technology 164-165 (2005) 1466-1471.
[18] S. Żółkiewski, Analysis of complex damped longitudinally vibrating systems in transportation, Journal of Achievements in Materials and Manufacturing Engineering 36/2 (2009) 176-183.