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Example of the analysis of mechanical system vibrations in GRAFSIM and CATGEN software

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Analysis and modelling

ABSTRACT

Purpose: The scope of the paper is to demonstrate the possibilities of GRAFSIM software used for modelling of vibrations of 2D and three- dimensional linearly coupled mechanical systems. Options of CATGEN application supporting the user in the transfer of data on the model generated in CATIA program to GRAFSIM are also discussed.

Design/methodology/approach: For the analysis of mechanical vibrations the software applies the matrix hybrid graphs and block diagrams method. On the grounds of the data derived from the examined dynamical system and entered into the program by its user, matrices characterizing the model are generated. In the course of numerical calculations the system is represented as a block diagram, and exposed to detailed analysis in Matlab-SIMULINK environment.

Findings: GRAFSIM and CATGEN software packages enable easy analyses of the vibrations of mechanical systems or of their parts. The tests may be run, for example, in view of the selection of elastic-damping connections between the inertial elements of the system.

Research limitations/implications: The paper is focused on modelling of vibrating systems in the form of a passenger car. Time responses of the vibrations of the system model evoked by various types of excitations are presented, as well as the amplitude –frequency –phase characteristics (a-c-f).

Originality/value: Valuable source of information for researchers into the theory of mechanical vibrations searching for a tool enabling the determination of the time responses and the amplitude –frequency –phase characteristics of machine and equipment parts.

Keywords: CAD/CAM; Applied mechanics; Vibration analysis; Matrix hybrid graphs

1. Introduction

Mechanical vibrations occurring in the course of machines operation constitute a major measure of their dynamical state [1]. To improve basic quality coefficients of machines, methods and means available should focus on reducing the amplitudes of vibrations and avoiding their free vibrations frequency. Although in some cases vibrations constitute working media deliberately introduced by designers as essential elements for the implementation of certain process technologies; in the majority of cases they exert negative impacts on the durability and reliability of machines and equipment. When transferred through direct contact with the vibrating source to human organisms, vibrations may have a detrimental impact on employees' health. The sources of undesirable vibrations of mechanical systems may be various: they may be caused by the structure of the system, i.e. wrong balance of its rotating elements, they may be evoked by external forces, such as, for example, uneven road pavement along which a machine or equipment moves.

However, it should be noted that mechanical vibrations provide invaluable information, as, on the bases of vibration.

signals analyses, it is possible to assess the technical condition of machines and their quality. Modelling is a very important issue involved in the analysis of the operation and synthesis of technical objects. It consists of selecting an idealized equivalent system, which makes it possible to recreate, with a certain approximation, the principles of the organization and operation of the object, deriving, consequently, the information on the modelled object itself. To create a physical and, in the next step, a mathematical model of the mechanical system in question, it is essential to know its properties, processes and correlations that occur in the system. In the majority of cases, mechanical models are constructed of rigid elements, connected by means of kinematical couples that secure proper mobility of the mechanisms making up the system and, at the same time, guarantee its correct performance. Due to their modular structure, such systems are mostly represented by physical models in the form of inertial elements systems, exposed to the influence of constraints and external forces.

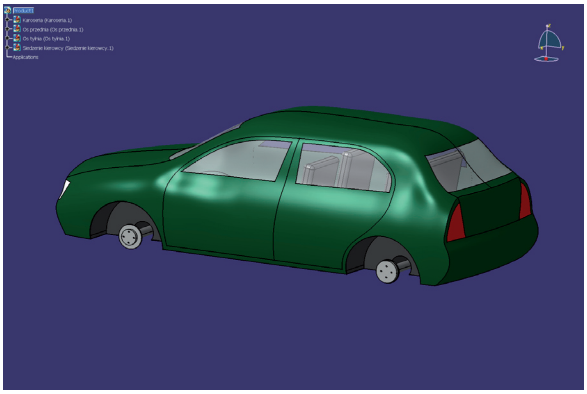

Fig.1. Model of a passenger car

Nowadays computer-aided techniques are commonly applied for modelling and testing mechanical vibrations. The use of advanced software for the analysis of vibrations is often grounded by economic factors, as the construction of models is very expensive and time consuming. There are numerous programs that can be applied for such tasks. Older versions are continuously updated and offer new options to their users. GRAFSIM software, developed at the Silesian University of Technology, supports the vibrations analysis of flat and three-dimensional mechanical systems [2-15].

The software works in MATLAB-SIMULINK environment. By means of several windows it enables the insertion of the data on the structure of the analyzed model. Next, on the basis of the assembled data, matrices characterizing the model are derived. In the course of numerical calculations the system is represented as a block diagram, which is subsequently subjected to further operations in SIMULINK environment.

GRAFSIM supports the simulations of complex models of mechanical systems with linear couplings. Such systems may be subjected to control operations in the form of dynamical excitations, kinematical excitations, or any initial conditions.

3D models of mechanical systems may be made in CATIA software, and the model parameters required for further analyses exported to GRAFSIM by means of CATGEN applications [8]. This software acts as an interface between CATIA and GRAFSIM. The final result of the running of CATGEN is an input file to GRAFSIM, by means of which it is possible to analyze the vibrations of any complex mechanical system.

2.Modelling the vibrations of mechanical systems supported by GRAFSIM and CATGEN software

The study on the modelling of a vibrating system in a form of a passenger car is discussed below. For the derived model, the characteristics describing its vibrations and resonance zones are determined.

First, a model of a passenger car was created in CATIA software. Depending on the needs, such model may be more or less complex. To present the possibilities of the software, a simple model shown in Fig. 1 was created.

Skoda Fabia car was used as a pattern for the model. The model reflects the main dimensions in relation to the original objects; furthermore, the coupling coordinates of certain elastic-damping elements (EDE) correspond to the coupling coordinates of shock absorbers and tyres in this car.

The materials allocated to particular elements of the model were selected in a manner securing the closest possible resemblance to the masses of the original object.

In the course of idealizing the real object in question, the following inertial elements were distinguished: body, front axle, rear axle and the driver's seat. All these elements are coupled with elastic-damping elements, comprising 11 items in the model: two shock absorbers, two springs, two vibration dampers, four tyres and the EDE coupling the body with the driver's seat.

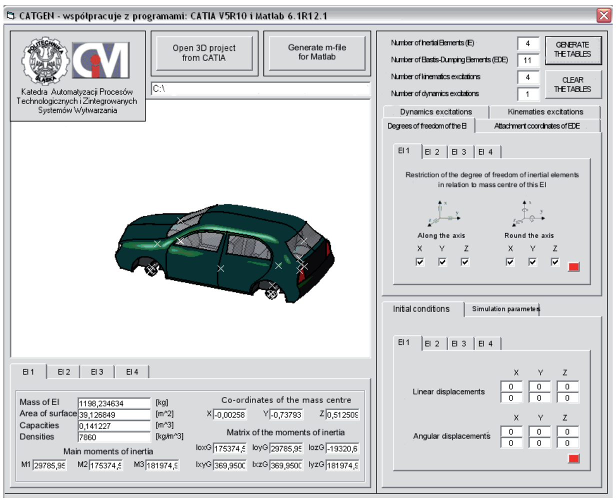

Fig. 2 View of the main window of CATGEN application

One of the inertial elements of the passenger car is the body. With the use of the elastic-damping elements it was coupled with the axles and the driver's seat was mounted in the body.

By means of CATGEN interface [8] all essentials parameters of the system created in CATIA are automatically downloaded: the data on inertial elements, coincidence points of elastic-damping elements, kinematical and dynamical excitations. CATGEN's main window with the inserted assembly file of the system model is shown in Fig.2. Several auxiliary steps must be carried out in CATIA- the coincidence points of the elastic-damping elements must be plotted on the system elements, and, in the next step, given a proper name.

The body is coupled with other inertial elements by means of elastic-damping elements: two shock absorbers (connecting the model with the front axle), springs and vibration dampers (connecting the model with the rear axle) and the elastic-damping element (at which the driver's seat is mounted to the car body).

The car body model is inserted into CATGEN. In Fig. 3 the data read by the software, i.e. the mass, coordinates of the centre of gravity and moments of inertia are presented.

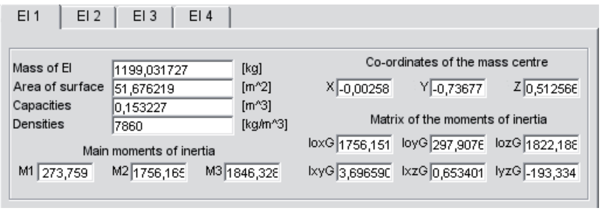

Fig. 3. Part of CATGEN window with the description of the car body

Using the appropriate windows of the software, the user may determine the elements exposed to the dynamical or kinematical excitations. The software renders wide options as to the selection of the excitation force. A random, sinusoidal, impulsive, step, rectangular, angular, cross-cut and trapezoidal function may be selected. It is also possible to declare any excitation function by introducing the user's own algebraic equation f(u). The kinematical excitation may be defined as a displacement, velocity or acceleration function, depending on the conditions that prevail in the discussed model of a mechanical system.

CATGEN can automatically read out the coupling coordinates of particular elastic-damping elements; whereas it is up to the user to designate the angles between the elastic-damping elements and particular coordinate systems axes of the inertial elements.

After all the interfaces are completed and the set-ups confirmed, the application generates the input file to GRAFSIM.

3. Numerical analysis

In the course of the analysis of a car model loaded by kinematical excitations, acting on the front left wheel of the car in the form of displacement impulsive function has been implemented. The impulse duration is 1[s] and its amplitude is 0,08 [m]. Traffic constraints were set on the vehicle, according to which it may only move in a vertical direction. In Fig 4 exemplary output functions derived in the course of the analyses are shown.

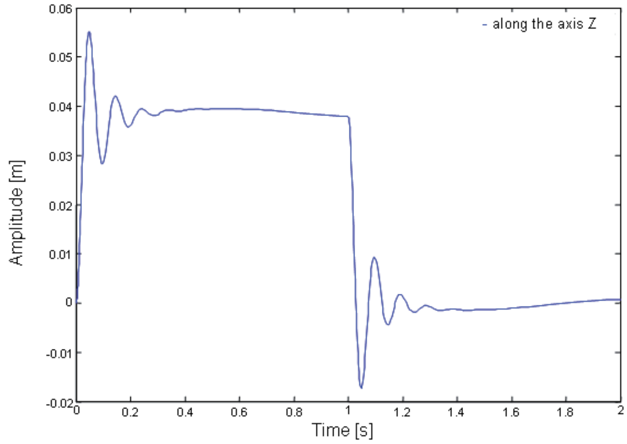

Fig.4. Graph of displacement changes as a response of the vehicle front axle to given kinematical excitation

Fig. 5 depicts the decibel amplitude-frequency-phase characteristics expressing relative changes in selected system parameters as a dynamical excitation function for a system with and without damping.

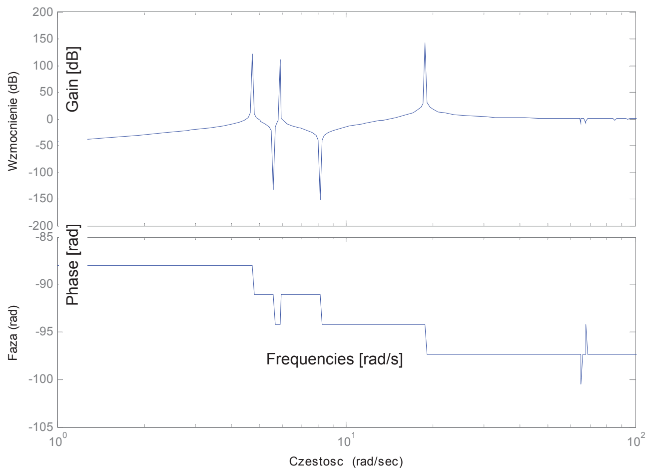

Fig. 5. Decibel amplitude-frequency-phase characteristics of the vehicle model expressing relative inertial force of the driver's seat with the driver as a dynamical excitation function acting upon the driver's seat in the direction of axle for free vibrations

It may be observed that vibrations are generated when the impulse is initiated and finished, and, next, they fade as a result of damping.

The analysis of the derived graph indicates that the maximal vibrations amplitude in the form of velocity of the centre of the driver's seat with the driver mass for linear velocity was 0.012[m/s].

The resonance frequencies of the free vibrations of the vehicle model calculated by means of GRAFSIM software are compiled in Table 1.

Table 1.
The resonance frequencies of the free vibrations of the vehicle model calculated by means of GRAFSIM software

	[rad/s]	[Hz]
1	3,41	0,54
2	5,87	0,94
3	6,84	1,09
4	21,03	3,35
5	65,05	10,40
6	67,36	10,70
7	85,08	13,50
8	94,25	15,00

4. Conclusions

The discussed method of the analysis of mechanical systems on the basis of block diagrams enables the insertion of control functions formulated in many ways, leading to the input function being treated as a disturbance or a control signal. The software makes it possible to generate the equations of state in view of the defined system inputs and outputs, as well as a matrix form of the block diagram.

On the grounds of the introduced data, software generates operating dynamical characteristics (transmittance), and, consequently, matrices of the state describing the analyzed model of a mechanical system. The software automatically designates equivalent transmittance of the system on the basis of the defined input and output of the block diagram, and, in the next step, determines the matrices of the state. The data on the dynamical characteristics of the system in the form of kinematical and dynamical excitations determined for any inputs and outputs constitute the basis for determining the frequency characteristics and time responses for the discussed class of mechanical systems.

GRAFSIM package with CATGEN application, which is used for collecting and preparing input data, provides a legible and user-friendly tool for the analysis of the vibrations of mechanical systems.

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