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Modelling of mechanical system vibrations by utilisation of the GRAFSIM software*

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Abstract: The article presents a modelling process and a numerical vibration analysis of the ABB 4400/60 robot model [5] by utilisation of GRAFSIM engineering program [1,3,4,6,7]. The model has a discrete distribution of the parameters and is considered in two working positions. It has been attracted to kinematic and dynamic excitations. The GRAFSIM program that has been used works on the basis that the algorithm transforms matrix hybrid graph model structures into block diagrams structures [6,7].

Keywords: Engineering software; Mechanical systems; Vibration analysis; Modelling

1. INTRODUCTION

Nowadays engineers must solve many various types of technical problems that are often connected with making a comprehensive analysis of mechanical systems vibrations. There are of course many engineering programs that engineers can use to achieve proper results of their researches. Many of these programs are being still developed very quickly world-wide. By using proper engineering software one can make a virtual model of an examined system in the computer software environment, which results in virtual prototyping of mechanical systems. This practical approach solves complex problems and has the ability to make various types of changes in parameters of a model during a simulation.

Advanced studies and researches are being conducted over new methods, which can free the user from creating and solving complicated differential equations. These properties are possessed by unclasical methods like polar, block, hybrid, bonds, transformation of variables and matrix hybrid graphs as well as structural numbers [1,2,3,4,6,7,8]. These methods, generally called network methods, suppress the problems of classical methods (they improve the automation of calculations, simultaneously making it possible to present graphically the structure of modelled mechanical systems).

For projects and analysis of mechanical systems many professional computer applications have been implemented. One of these programs is GRAFSIM, which was implemented in the MATLAB-SIMULINK software environment. It illustrates how the algorithm transforms

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matrix hybrid graph of the mechanical system into a block diagram structure, which was described in details in works [6,7]. The program gives possibility to test 3-dimensional, multi-input and multi-output dynamical systems, which are heterogeneous, due to the configuration of mechanical variables, and to the characteristic distribution of the parameters of elements making up the model.

The algebraic expressions of transformation into the block diagram constitute the basis for applying the method to test the dynamics of vibrating systems with non-linear elements and give possibility to generate, besides dynamical characteristics, their time responses.

In that case whatever complicated model of a mechanical system after its transformation through a matrix hybrid graph into a block diagram, could have been further tested in that program.

2. MODEL

The ABB 4400/60 is a compact robot [5] with medium to heavy handling capacity. It can handle loads up to 60 kg, or up to 45 kg at very high speeds. It can be used for material handling, machine tending, grinding, polishing, scaling, gluing, assembly, spraying and cutting.

Two positions of the robot arms were accepted for numerical analysis and are presented on Figure 1.

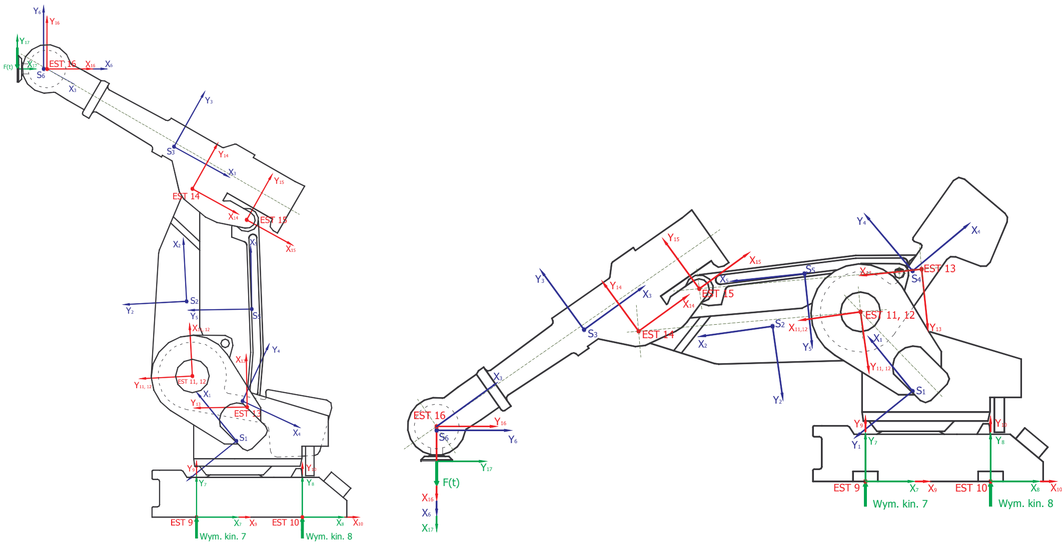

Figure 1. Discrete phenomenological model of the robot with the points of coincidence distances from the mass centres of the inertial elements in two working positions

After idealisation and discretisation process the following simplifications were taken into consideration:

1. Phenomenological model of a mechanical system has been accepted in the following form:
   - system (Figure 1) is considered as 2 dimensional with:
     - 6 inertial elements such like: robot basis, column of the robot, arm, counterbalance, connecting rod, mount of the gripper,
     - 7 elastic-dumping elements,
     - 2 kinematic and 1 dynamic excitations.

2. Masses and inertial elements moments of inertia of the accepted model of the system, the linear and angular elasticity of the elastic elements, the linear and angular suppressions of the dumping elements.
3. The local co-ordinate systems of inertial elements, elastic-dumping elements and kinematic and dynamic excitations (Figure 1).
4. The attachment co-ordinates of elastic-dumping elements in local co-ordinate systems of inertial elements, with which they are incident and angles between co-ordinate systems of elastic-dumping elements and inertial elements (Figure 1).
5. Attachment co-ordinates of dynamic excitation in local co-ordinate system of inertial element, with which it is incident and angles between co-ordinate system of dynamic excitation and that inertial element.
6. Angles among kinematic excitations co-ordinate systems and elastic-dumping elements.
7. Numbers of all elements of modelled dynamic system in following order:

3. ANALYSIS RESULTS

After determining geometrical and physical structure of the robot model its analysis was performed and results were obtained in two working positions of the robot's equipment. Some of these results are presented at the shareable graphs in this article. The amplitude of the accepted kinematic excitations in the shape of sinusoidal functions is $3 \cdot 10^{-3}$ [m], frequency 5,5 [Hz]. Dynamic excitation, accepted in the GRAFSIM program, that in analysed case constitute the carried element mass was considered as harmonic function about amplitude 300 [N], frequency 5 [Hz] and with zero angle of phase displacement. Changes of inertia forces [N] and displacement [m] in the x and y axes directions of the mount of the gripper in time, as response on kinematic and dynamic excitations have been presented on Figure 2.

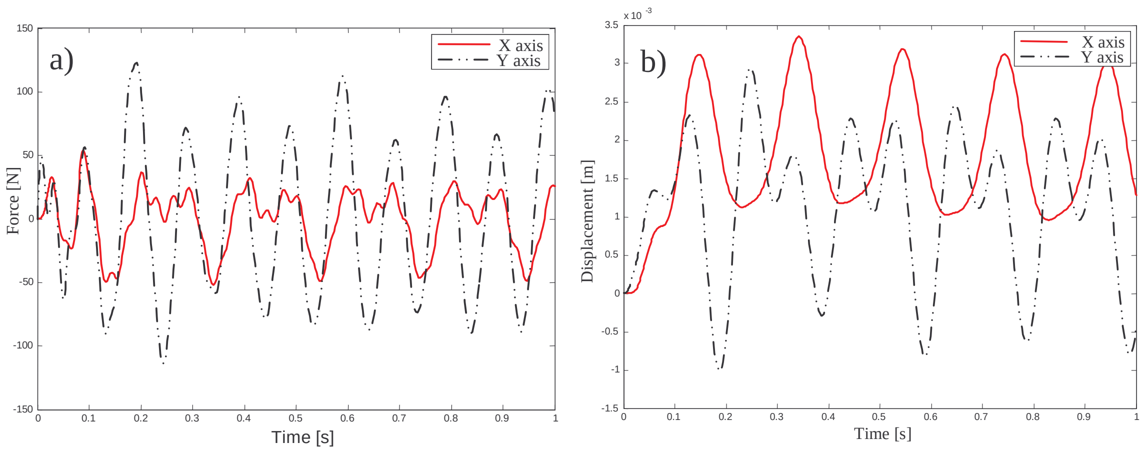

Figure 2. Changes of inertia forces [N] (a) and displacement [m] (b) in the x and y axes directions of the mount of the gripper in time, as response on kinematic and dynamic excitations in first working position

Time responses from set kinematic and dynamic excitations (Figure 2) were generated for simulation time t = 1 [s]. The maximum vibration amplitude in the shape of inertia force [N] in the y axis direction of the operator and his seat achieves value 120 [N] in the 1st position of the robot, however in 2nd position - 100 [N] value. In the graph of displacement changes of the mount of the gripper in the function of accepted excitations in time it is possible to noticed that the maximum vibration amplitude in the shape of displacement equals $3{,}2\cdot10^{-3}$ [m] in first position and $5\cdot10^{-3}$ [m]- in second (graph not presented in article).

3. CONCLUSIONS

The GRAFSIM program gave the possibility to generate time responses on individual dynamical and kinematical excitations, to show zeroes and poles of characteristic equations on the complex surface and in a tabular form, and to generate state matrix equations of a discrete model of the mechanical system.

But by bringing in certain program working conditions, many types of numerical data that represented examined system had to be determined during modelling process directly by user through a suitable interface system. This process of enquiring input data to the program is time-consuming and sometimes susceptible on human-made mistakes. Some further works are being made to avoid these shortcomings and will be presented in other works.

A vast other analysis of the robot model was carried out with series of dynamic and time response characteristics. The main reason of performed analysis was to show the GRAFSIM program possibilities, with utilisation of transformation method introduced in work [3,6,7]. Physical and geometrical data, especially the elastic-dumping parameters of the excavator model (not presented in the article) have been estimated, without carrying out expensive identification process of these parameters.

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