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SIMULATION OF ELASTIC VIBRATIONS OF CRANE INSTALLATIONS CONSTRUCTIONS IN COMSOL MULTIPHYSICS PACKAGE

The research considers the peculiarities of simulation of mechanical constructions elastic vibrations in software package Comsol Multiphysics. On the example of traveling crane and tower crane the technique of models development in the given package is shown.

Key words: *Comsol Multiphysics, elastic vibrations, crane.*

Automation of loads transportation processes by means of crane installations is very urgent problem as it allows to save electric energy and reduce the time of transportation. In this case, the synthesis of regulators and deduction of control laws is often performed without the account of elastic properties of mechanical part of crane installations. However, with the increase of constructions lengths their elastic vibrations result in considerable growth of mechanical stresses that reduces the term of cranes operation due to fatigue of metal.

The characteristic feature of extent constructions is distribution of their mass and rigidity along their length. In this case elastic vibrations are described by differential equations in partial derivatives, solved by the method of finite elements. That is why, nowadays, for the solution of such problems specialized program packages, oriented on studying the objects with distributed parameters, are often used.

The aim of the given research is development of the models of tower and traveling cranes constructions and investigation of the process of their transportation in Comsol Multiphysics package.

Creation of the model in the considered program package is carried out in several stages. First, it is necessary to set the dimensionality of graphic space. To simplify the models of the objects, having axis of symmetry in the construction, the possibility of creation of axis symmetrical models, comprising only the part of the whole construction, is provided. Secondly, the area of investigated physical phenomena and the type of the of the problem, being solved, is indicated, for instance, static or transition mode, natural vibrations frequency, etc. After that, it is necessary to form the geometry of the object under investigation, for this purpose we have rather convenient graphic interface and there exists the possibility to import the models, created in specialized graphic editors.

The next step is the description of the physical properties of the material, the construction is made of. The list of parameters, necessary for calculation, depends on what branch of physics the phenomena being investigated, refer to. For instance, magnetic fields require information regarding relative permeability of the material and its electric conduction and investigation of mechanical vibrations of the construction requires information about Young's modulus, Poisson's ratio, tightness of the chosen material, etc.

The last step of model creation is the description of all external impacts, ways of objects interaction and prohibition for transportation in certain directions.

For simulation of processes in mechanical systems in Comsol Multiphysics package module Structural Mechanics is applied, the module comprises various libraries, intended for the simulation of specific systems. Particularly, simulation of elastic vibrations of constructions within the limits of material flow zone is possible by means of libraries Solid, Shell and Beam. Each of these libraries has limitations, regarding the possibility of displacements and their derivatives. The library of solids enables to measure speeds and accelerations along all three axes but does not give information regarding the rotation angles, library of shell does not allow to measure linear speeds and angular accelerations and Beam library allows to measure and speeds and accelerations. These peculiarities should be taken into account while model development.

As the example we will consider the process of travelling crane model creation (see Fig. 1). We

will assume as a basis the data of the travelling crane 5+5-5K-22,5-10 Y2. Proceeding from the assumptions, that in greater part of cases the external regulation contour in the system of automated electric drive of the crane is speed contour, library Solid Mechanics is used for creation of the model, the library enables to calculate linear speed in any direction at any point of the construction.

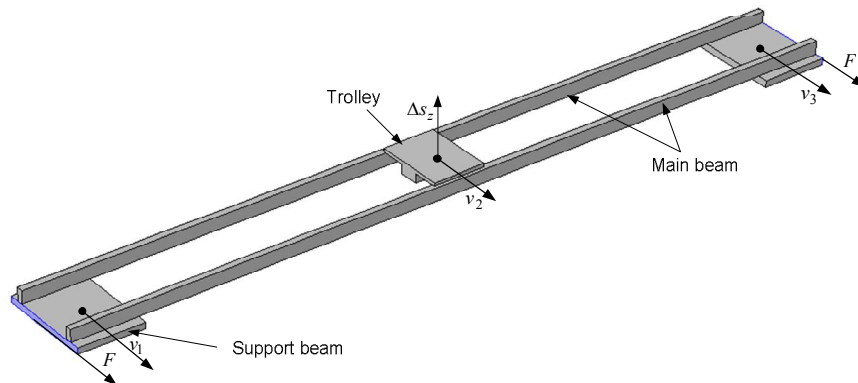


Fig. 1. Model of travelling crane

The accuracy of modeling results, obtained from this model, will depend on the degree of correspondence of model geometry to real dimensions of the installation. It should be taken into account, that availability of small pieces in the construction leads to considerable increase of the volume of machine memory, needed for computations. That is why, it is expedient to realize the construction in the form of the set of beams, section of which corresponds to the dimensions of the considered crane. In this case the mass of construction drastically increases, that is why it is necessary to reduce density and rigidity of the material, it is made of.

Besides this, modeling of the process of load rocking and lifting is rather complicated, due to the lack of the possibility to create articulated joints and flexible rapes, and realization of trolley motion across the bridge is connected with certain difficulties. That is why, we will be limited by one charging trolley without load, rigidly fixed at a certain point of bridge construction.

Neglecting the elasticity of the contact between the rail and the wheel, we may assume that the beams of the crane cannot move in transversal direction and in vertical direction, that is realized only by means of prohibiting of travelling of low sides of supporting beams. Force, produced by drive motors, can be realized, applying the equivalent by its value, force to the extreme sides of supporting beams in the direction of bridge travelling. The action of gravitational force can be taken into consideration, introducing the force, distributed along the while volume of the construction, calculated as $F = g\rho$, where ρ – is the density of the material.

Having installed the trolley in the middle point and applied the force during 1 sec to the extreme sides, we obtain the diagrams of speed components by two axes: horizontal, along which the motion is realized and vertical, shown in Fig. 2.

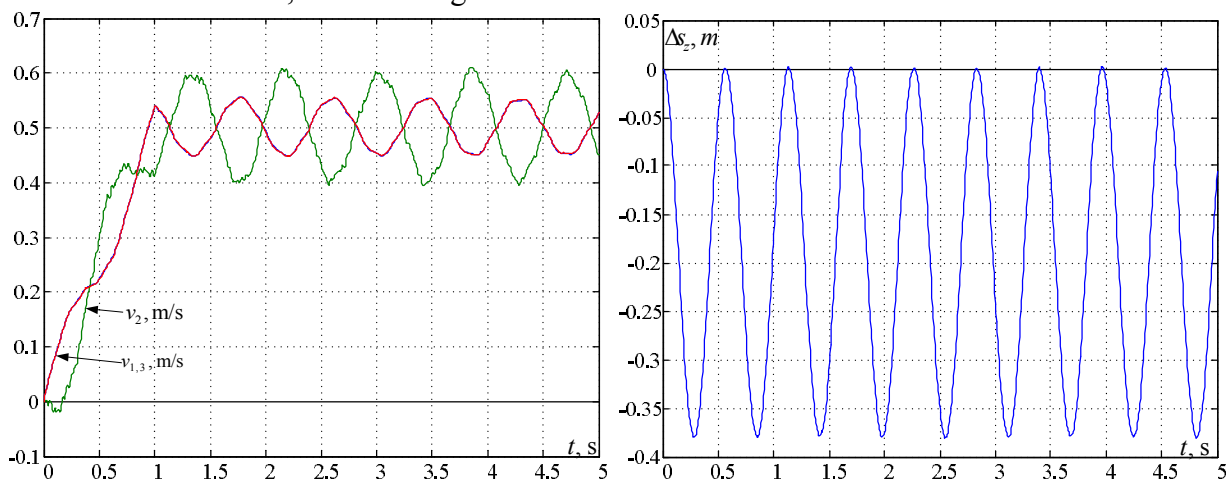


Fig. 2. Graphs of horizontal speeds and vertical deformation at the central location of the trolley

Diagrams of horizontal speeds have been obtained for extreme points of the construction and for trolley. Vertical movements are possible only for main beams, that is why, value of beams deformation in vertical direction we fix in the point, where the trolley is installed. It is obvious, that due to the symmetry of the construction, the speeds in extreme points are absolutely identical. Vertical vibrations are of undamped character, since the forces of internal friction were not taken into account in the process of model creation.

Fig. 3 shows the graphs of the same signals, when forces of internal friction are taken into account. In the given case gradual damping of vibrations is observed, the damping is stronger when their frequency is higher.

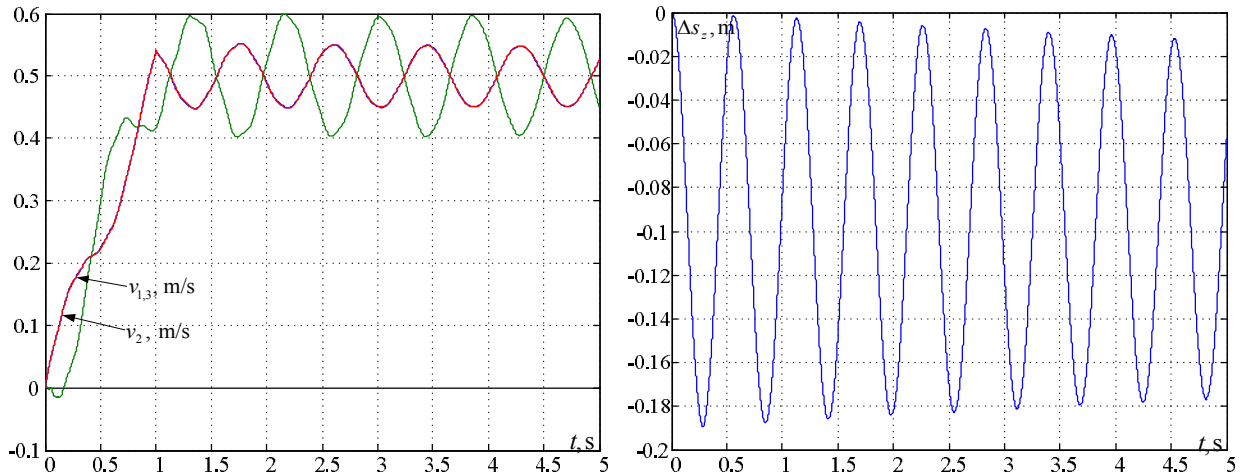


Fig. 3. Graphs of horizontal speeds and vertical deformation when internal friction forces are taken into account

Thus, the developed model enables to carry out the research of elastic vibrations of travelling crane construction at different positions of the trolley and impact of various forces.

More complex is the process of creation of tower crane model, since it has lattice structure, consisting of a great number of beams of different cross-section. On one hand, all the beams can be presented in the form of shells, as the thicknesses of the applied profiles are insignificant as compared with the length of each separately taken element. On the other hand, the process of creation of such model is very complicated; and the process of modeling requires large computational power. Having built the construction from solids we could achieve the sufficient simplicity of the model at minor losses of accuracy of the results. Proceeding from these assumptions, we will construct the model of tower crane of thin beam elements, each of which corresponds certain cross-section, determining its rigidity in all the directions. As the reference data for the creation of the model, the information concerning crane WOLFF 6071 manufactured by the company Wolfkran AG was used. The developed model is shown in Fig. 4.

While creation of the given model certain assumptions were taken. Particularly, the trolley with the suspended load was excluded from the calculation. Unlike the travelling crane, load trolley has far less mass, that is why, its impact on the dynamics of the whole system is not significant. Drives of trolley motion and load lifting, as well as counter weight are presented in the form of localized mass, located in the points, indicated in Fig. 4.

Taking into consideration that the library of beams does not allow to perform speed measurements and in transient processes elastic vibrations are for less expressive, we will take, as signal being measured, the difference of turning angles between the points, located on the axis of rotation and at the end of the boom. The obtain graph is shown in Fig. 5.

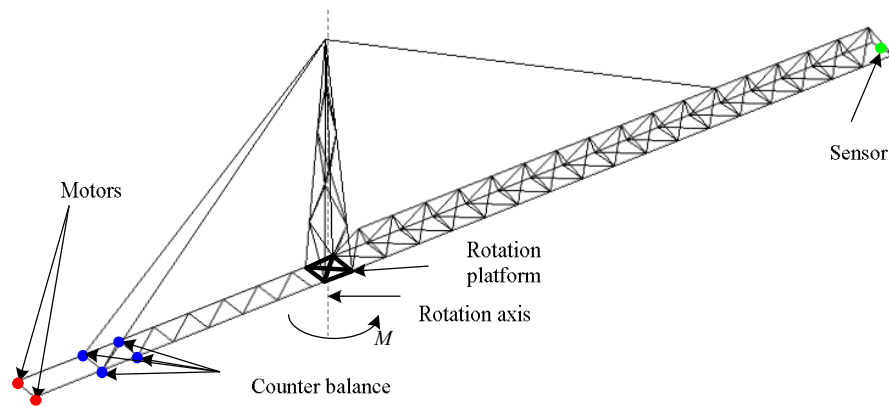


Fig. 4. Model of tower crane

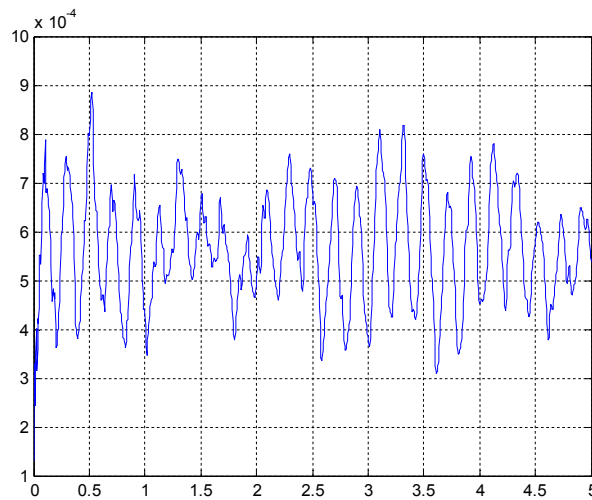


Fig. 5. Difference of angles of swing of a boom

It is obvious, that the character of vibrations as compared with travelling crane is more complicated. There are several harmonic components, each of which corresponds to certain mode of natural elastic vibrations of the construction. Having completed the model with gravitational force or applying to the beams certain load, simulating the impact of the wind, analog graphs, showing the peculiarities of the deformation of the construction in this or that case can be obtained.

Conclusions. Comsol Multiphysics package enables to develop models, which rather accurately describe the dynamics of elastic mechanical constructions. Using the given technique the model of the construction of optional crane installation can be developed and the study of its elastic vibration can be carried out.

REFERENCES

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