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EFFICIENT METHOD FOR THE CALCULATION OF WAVE PROPAGATION IN RODS SUBJECT TO IMPACT LOADING

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ABSTRACT

There is considered an algorithm for calculating propagation of longitudinal and bending deformations' waves in the rod systems, caused by the action of short-term impact impulse. To describe the transverse oscillations of rods the Tymoshenko's equation was used. There were received the wave reflection and refraction coefficients in the images space of the Laplace transform by time. The comparison of the results was performed for the accelerations calculation of the deformation wave propagation through a rod system node obtained by the proposed method and by the finite element method.

Keywords: elastic waves, rod systems, Laplace transform, Tymoshenko's equation.

INTRODUCTION

To solve a number of technical problems it is necessary to study the dynamics of rod systems with mutually perpendicular rods under the action of short-term concentrated forces, for example, a problem of oscillations of industrial precipitator electrostatic electrode elements during their shaking off adhering dust (Fedorov, 2013). Modern software tools for the finite element modeling allow us to solve the problem of wave propagation in the rod systems, but the procedure of such simulations is very time-consuming. Therefore, it is interesting the development of analytical methods (Antes, 2004) allowing to analyze the parameters of construction oscillations quickly.

The presented investigation demonstrates a solution obtained by Laplace transform by time for the problem of determining the internal forces and accelerations in the rod system elements under the action of a short-term point force. It was assumed that the longitudinal oscillations of the rods are described by the classic wave equation, the transverse oscillations - by the Tymoshenko's equation (Timoshenko, 1974). Based on the analysis of wave propagation through the rod system node with one finite length rod and three semi-infinite rods, there were developed the equations for the wave refraction and reflection coefficients in the image space. In order to perform the inverse transformation it was performed the decomposition of the equations in a series of powers of the Laplace transform parameter. This allowed to obtain an approximate solution, which is a power series in time.

To analyze the accuracy of the results it was carried out the simulation of the deformation and stress waves' propagation through the rod system node by finite element method realized using the ANSYS software. The construction elements were modeled as the 8-node brick finite elements.

RESULTS AND CONCLUSIONS

On the base of the obtained equations and finite element computation there was performed a simulation of the deformation waves' propagation in a steel rod system consisting of four mutually perpendicular rods with a square cross section (fig. 1). The length of the cross section side is 1 cm. It was assumed that an evenly distributed pressure was applied to the rod 1 end. This pressure changed as a half-wave sine wave of 1.25 MPa amplitude during 80 microseconds. Table 1 demonstrates the maximal acceleration values obtained by the finite element and analytical methods for the case only the first term of the series hold. Here a_0 - initial acceleration (of the rod 1 points immediately after it was hit) in the incoming wave on the node, a_1 - acceleration of the rod 1 points after wave reflection from the node, a_2, a_3, a_4 - accelerations in the rod 2, 3, 4 points.

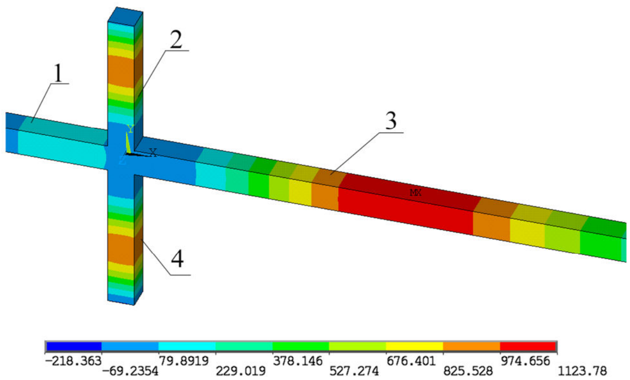

Fig. 1 - Acceleration (m/s^2) distribution scheme in the system elements

Table 1 - Comparison of acceleration values (m/s^2), obtained by the finite element and analytical methods

Calculation method	a_0	a_1	$a_{2,4}$	a_3
Finite element simulation	1464	508	393	1097
Analytical calculation	1464	534	432	999

The computational results show that the acceleration values obtained by the analytical and finite element method differ by less than 10%. This fact confirms the possibility of the suggested approach application for the operative evaluation of the acceleration values for rod systems points at an impact. The consistent application of these expressions to multiple nodes allows the carry out a complete computation of wave propagation in a complex rod system. At the same time, the analytical solution requires ten times less time to be done comparing with the time necessary to create a model and to perform finite element analysis.

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