Comparison of finite element modeling and analytical approach results for oscillating rod structure with crack

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Annotation: the paper considers the comparison of natural modes for the first and second transverse oscillation modes obtained by numerical simulation and finite element package of analytical calculation of the core model with an elastic element based on the application of the Euler-Bernoulli hypothesis. The analysis compared waveforms for different values of the defect shows their satisfactory agreement.
Keywords: rod design, vibrations, defect, finite element modeling, analytical modeling, waveform

Problems identifying damage in rod structures in a large number of works presented in the review, published not only for a long time, but in recent years [1-12]. Construction of algorithms for solving problems of identification based on selected methods of calculation takes an important place in the study of damaged structures. In recent years, often used a relatively new approach of the development and application of evolutionary algorithms, neural networks and optimization methods [13-14].

An important factor in the identification of defects is the use of sophisticated models as an example of using the finite element approach, and an example of simple Euler-Bernoulli hypothesis [15], and require their comparison

The aim of the work is to compare the natural shapes of the first two modes of transverse vibrations of a rod model. Additional information in this method of identification of damage is a set of natural frequencies obtained from the analytical calculation for the core structure with different sizes of the defect, which is located in a particular place [16].

Model of a cantilever beam with a crack. We consider a cantilever beam of length L of rectangular cross-section (height h, width b) with a transverse notch depth t, located at a distance L_c from the termination (see Fig. 1).

Finite-element full-bodied and a simple analytical model of defective design is presented in [16]. Analytical modeling was based on a composite beam, in which the incision is replaced by an elastic element (spring) with a constant flexural rigidity.

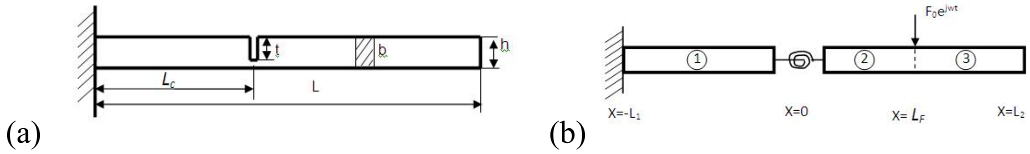

Fig. 1. (a) Scheme of the cantilever beam to damage a notch and (b) a composite model of a cantilever beam with an elastic element

Were calculated and compared waveforms obtained by numerical simulation and finite element package of analytical calculation of the core of the simplified model with an elastic element. Modal analysis was carried out for models with the location of the defect $\overline{L}_c = 0.25$. Analyzed a model with two values of the defect $\bar{t} = 0.3$ and $\bar{t} = 0.7$. When calculated using the numerical expression (6) of [16], the flexural rigidity $K_t(\bar{t})$ of the elastic element to the analytical model were as follows: $K_t(0.7) = 262$ Nm / rad and $K_t(0.3) = 3569$ Nm / rad.

Fig. 2 shows the form of the 1st (a, b), 2nd (c, d) modes of transverse vibrations resulting from FE and analytical calculations for the size of the defect (a, c) and (b, d). For comparison, the amplitude of the vibration modes were dimensionless to the amplitude of the oscillation at a point along the length of the bar, located at the free end $\bar{x} = 1$.

At the location of the defect has a kink waveform, which is clearly evident in the third and fourth modes of oscillation at the value of the defect $\bar{t} = 0.3$ and all selected forms of vibrational modes at a value $\bar{t} = 0.7$ for both models. Compared waveforms obtained based on an analytical calculation waveforms obtained by FE at each point along the length of the rod. The relative magnitude of the amplitude waveforms at various points along the length of the rod is calculated as follows:

$$\Delta\overline{A} = \frac{\left|\overline{A}_{ан\,р} - \overline{A}_{кэ}\right|}{\overline{A}_{\max\,кэ}} 100\% . \qquad (1)$$

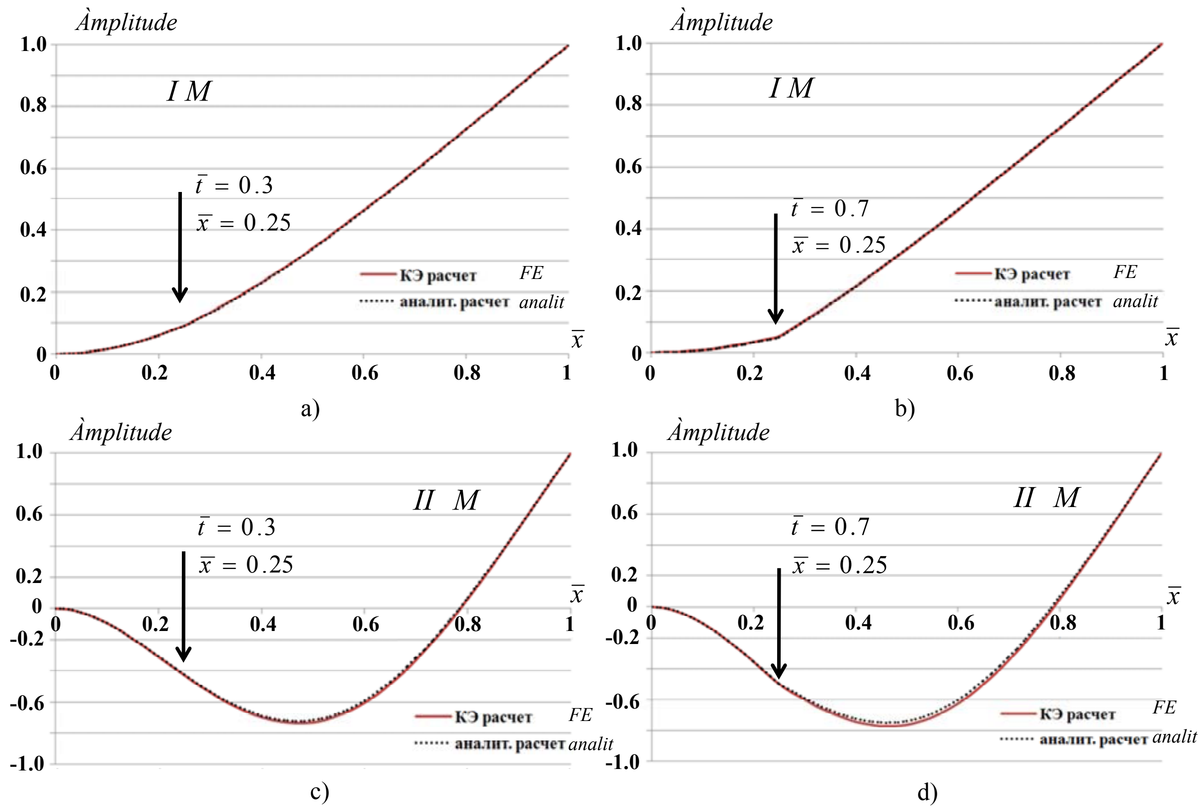

Fig. 2. Forms the 1st (a, b), the 2nd (c, d), transverse mode vibrations resulting FE and analytical calculations for modal quantities crack $\bar{t} = 0.3$ (a, b) and $\bar{t} = 0.7$ (c, d)

Analysis comparing the corresponding curves waveforms showed the following. When comparing the amplitudes of the corresponding points along the length of the rod forms of the first oscillation mode the maximum difference is at the value of $\bar{t} = 0.3$ $\Delta\bar{A}_{max} = 0.2\%$ of the defect and $\bar{t} = 0.7$ $\Delta\bar{A}_{max} = 1.2\%$. The maximum amplitude difference lies in the vicinity of the location of the defect

When comparing the amplitudes of the corresponding points along the length of the rod shape of the second mode oscillation maximum difference is at the value of $\bar{t} = 0.3$ $\Delta\bar{A}_{max} = 1.47\%$ and a defect at $\bar{t} = 0.7$ $\Delta\bar{A}_{max} = 2.61\%$. The maximum difference of the amplitudes waveforms observed in inflection waveforms ($\bar{x} =$ 0.61). In the vicinity of the location of the defect for the two variants quantities divergence amplitudes of the second waveform does not exceed $\Delta\bar{A}_{max} = 0.39\%$.

Comparison of the amplitudes of the corresponding points along the length of the rod shape of the third oscillation mode shows that the maximum difference of the amplitudes of the defect at the value of $\bar{t}=0.3$ $\Delta\bar{A}_{\max}=2.7\%$ and $\bar{t}=0.7$ $\Delta\bar{A}_{\max}=6.5\%$. The maximum difference of the amplitudes correspond to the points of the rod in the vicinity of the location of the defect for the two variants quantities.

Comparison of the amplitudes of the corresponding points along the length of the rod forms the fourth oscillation mode shows that the maximum difference is at the value of $\bar{t}=0.3$ $\Delta\bar{A}_{\max}=1.49\%$ of the defect and $\bar{t}=0.7$ $\Delta\bar{A}_{\max}=4.7\%$. Maximum differences correspond to the amplitudes in the neighborhood of the location of the defect.

Conclusions. The analysis compared waveforms for different values of the defect shows that the qualitative characteristics of the curves forms of oscillations in the vicinity of the location of the defect, and along the length of the rod, the same for both models.

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