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ANALYSIS OF OSCILLATION FORMS AT DEFECT IDENTIFICATION IN NODE OF TRUSS BASED ON FINITE ELEMENT MODELING

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Abstract. The finite element modeling of the truss structure in ANSYS software is considered. The problem of the identification of defects in the truss rod construction was considered on the base of an analysis of the parameters of the vibration modes. A truss rod construction with two defects was modeled. The deflection and curvature of the vibration modes are analyzed. Defective elements are represented in the form of a change in the construction parameter of cross-section, localized in the vicinity of one of the junction nodes of the truss and fastening the rod. Modal analysis of the structure is carried out. The dependence of the eigen-frequencies and parameters of the vibration modes on the magnitude of the defect is considered. The analysis shows that the modal identification signs allow us to identify the defective node in the construction.

Keywords: truss structure; finite element modeling; ANSYS; oscillation forms; identification of defects; modal analysis.

1. Introduction

Some theoretical and experimental research approaches, and developed techniques for vibration diagnostics of rod structures are present in [1 – 5]. Analysis of this area allows us to make conclusions about its sufficient relevance.

In majority works, simple structural elements of a rod full-body or tube configuration with various structural defects are investigated, the most applicable of which is the defect model of crack-like configuration. Numerical analytical and experimental methods are used to analyze the vibration parameters and solve identification problems [5 – 8]. The most common method of identification is the use of resonance methods of free and forced oscillations and in part acoustic methods of control. Some modern approaches and algorithms to solve the problem of identifying defects, based on vibration diagnostics methods are present in [8 – 13]. The authors in these publications represent the solution of diagnostic problems, which is based on the use of correlation relationships between the parameters of the frequency spectrum of vibrations and the magnitude of damage to construction elements. In these studies, simple elements of the rod configuration are investigated. Approaches to the evaluation of damage, designs, based on the analysis of natural frequencies are an indirect sign of the assessment and cannot be applied to an accurate determination of the amount of damage to its elements.

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A more accurate method for identifying the parameters of defects is the method, based on the analysis of natural oscillations, and also the application of evolutionary algorithms presented, for example in [14, 15]. This approach allows us to find not only the magnitude, but also the exact localization of the defect in single construction element. Examples of modeling and analysis of vibrations of truss constructions with damage are present in [16 – 18].

The aim of the work is the identification of defects in the model of bridge truss construction with the rod configuration of its elements, based on the analysis of natural frequencies and vibration modes, using the finite element method in finite-element ANSYS software.

2. Modeling

As a research object, a model of a section of a bridge truss structure with rod elements was chosen (Fig. 1). The model of the truss structure can have multiple defects, located in certain nodes. The model has rigid fixation of displacements in all directions in the support nodes 3 and 4 of the fixing; moreover, vertical displacements are fixed in the nodes 1 and 2 of the model. At simplified modeling in ANSYS software, a rod-type finite element of the *Beam188* type is used as a structural element. The element is constructed on the base of the application of the Tymoshenko beam hypothesis. The cross-section of the element is rectangular full-bodied and have the sizes: a length of rod element is L = 250 mm, a height of cross-section is $h = 8$ mm, a width is $b = 4$ mm). Defects were modeled as a reduction in the cross-section on height and have a width of l_d = 1 mm, in the vicinity of the node of one of the rods of the lower belt of the construction (Fig. 1). The magnitude of the defect was calculated as the ratio of the height of the damaged (residual) cross-section to the original one: $t_d = (h - h_d)/h$.

For symmetry in the ZOX plane, the construction had two defects of the same configuration on both sides.

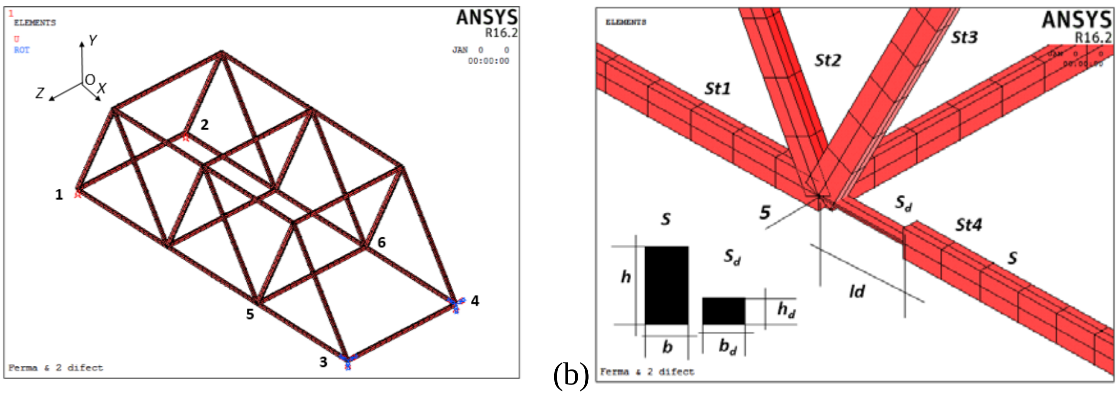
(a) (b)


Fig. 1. Scheme of the model of truss construction (a) and the node with the defect model (b).

3. Model description

The natural oscillations of the model are considered and compared in two cases: (i) without damage at the nodes, and (ii) existence of defects with a size t_d = 0.875. The first ten eigen-frequencies were calculated with the defect value (Table 1). Forms of oscillations of the model are constructed, and deflections and curvature of the construction are obtained at the first eigen-mode of the oscillations. The analysis of the results shows that for the case with two defects in given places, the frequencies of the first 10 modes of oscillation vary within the range $\Delta\omega$ = – 0.32 to – 1.65%.

Figure 2 shows the first 10 forms of the eigen-modes of the vibrations of the defect model. Analysis of vibration modes shows that 1 – 6 modes of natural modes of the model differ from 7 – 10 modes of oscillations in that all the nodes of the model are displaced. For 7 – 10 oscillation modes, the nodes have minimal spatial displacements.

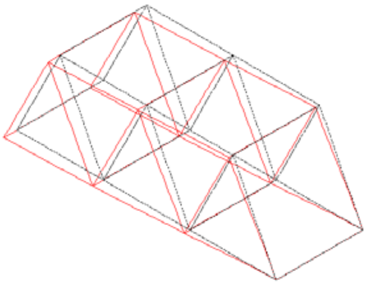
In the next step, the deformations in the direction of *z*-axis of the points of the rod truss were calculated at the first mode of oscillation in the vicinity of node 5, and the deflections and curvature were compared for the two cases of the models of the construction considered.

Table 1. Proper defect frequencies and their relative values.

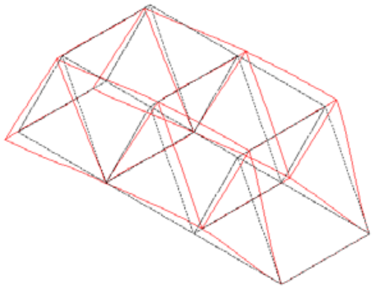
Mode, i	Natural frequencies ω_i (Hz)		Relative frequencies
	$t_d = 0$	$t_d = 0.875$	$\Delta\omega_i$ (%)
1	11.05	10.9	–1.33
2	34.67	34.1	–1.65
3	57.08	56.9	–0.32
4	57.47	57.1	–0.64
5	76.12	75.3	–1.07
6	79.12	78.6	–0.65
7	161.02	159.4	–1.01
8	161.95	160.4	–0.96
9	179.43	177.0	–1.35
10	188.03	185.6	–1.29

Figures 2 and 3 show the projections on *x*-axis of the amplitudes of the vibration modes and the curvature of the first mode for rods near the node 5. The *x*-axes of the graphs shows the coordinates of the points for the oscillation amplitudes; along *y*-axes of the graphs, the projections of the amplitude values of the waveforms and curvature in the *z*-direction of the construction are presented.

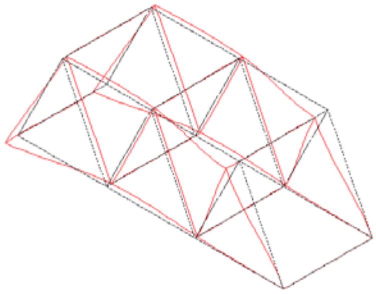
Analysis shows that near node point, the oscillation amplitude difference in the *z*-direction for four rods is minimal, as can be seen from the graphical representation of the vibration forms (Fig. 3). At the same time, the analysis of the plots of curvature forms in the *z*-direction (Fig. 4) shows some discrepancy between the plots when their intersection point is restored. This sign may be sufficient grounds for detecting a defect in a construction node.



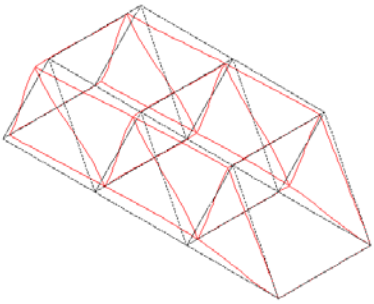
1 mode, ω_1 = 10.9 Hz



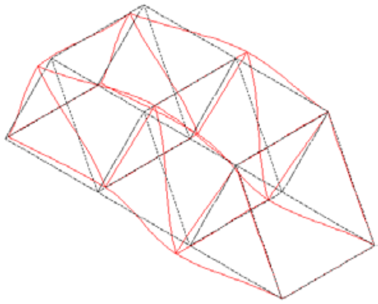
2 mode, ω_2 = 34.2 Hz



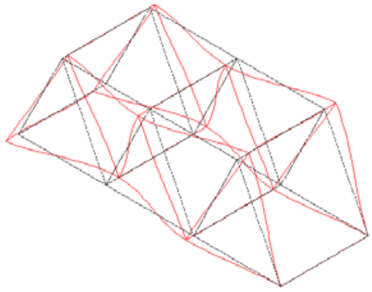
3 mode, ω_3 = 56.9 Hz



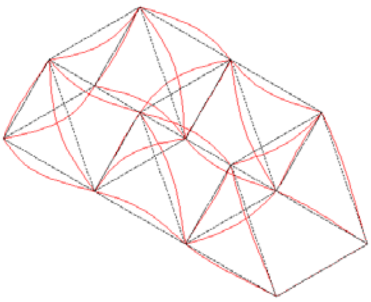
4 mode, ω_4 = 57.0 Hz



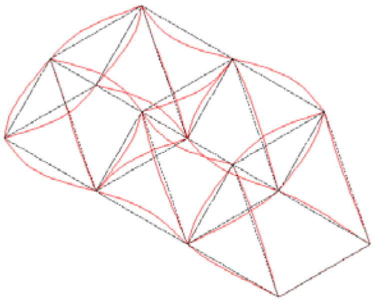
5 mode, ω_5 =75.3 Hz



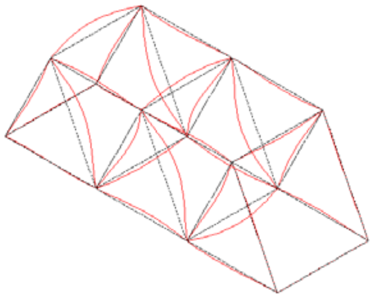
6 mode, ω_6 = 78.6 Hz



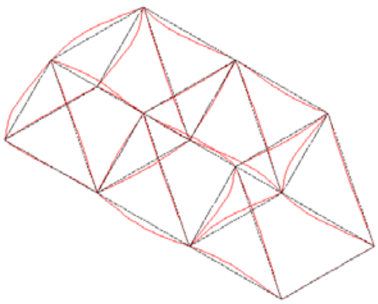
7 mode, ω_7 = 159.3 Hz



8 mode, ω_8 = 160.4 Hz

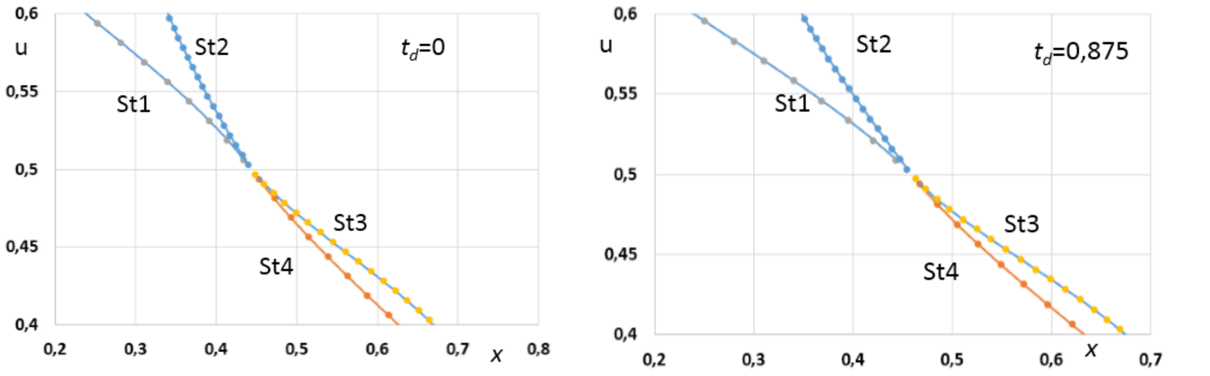


9 mode, ω_9 = 177.0 Hz



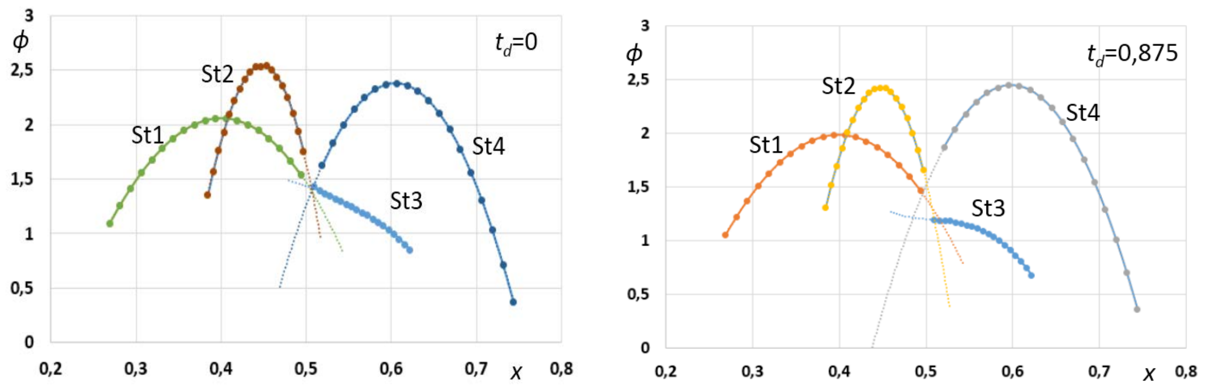
10 mode, ω_{10} = 185.6 Hz

Fig. 2. Eigen-forms for 10 modes of vibrations of the truss structure.



(a) (b)

Fig. 3. Shapes of the structure in z-direction near the node 5 for two cases of models.



(a) (b)

Fig. 4. Curvature of vibration mode 1 in z-direction of the rod construction near the node 5 with two versions of models: (a) without defect; (b) with defects.

Conclusions

The study of vibration in truss rod construction can be applied to the assessment of the presence of defects in a construction node. At the beginning investigation of the curvature of the oscillation forms of the truss at various vibration modes, nodes with defects can be identified. The analysis of the curvature parameters can be applied to the evaluation of the damage value in the rod junction assembly.

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