INFLUENCE OF THE PARAMETERS OF A LOCAL DEFECT IN A REGULAR SYSTEM
ON THE RANGE OF EIGENFREQUENCIES OF VIBRATIONS
AND THE LEVEL OF VIBRATION STRESSES IN ELEMENTS OF THE SAME TYPE

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We describe the results of our experimental investigations aimed at the analysis of the influence of the parameters of defects in the form of open edge cracks (depth and location) on the formation of the spectrum of eigenfrequencies and the level of vibration stresses in similar elements of a regular system. It is shown that our results are in good agreement with the results of computations.

Keywords: regular system, subsystem, detuning of vibration frequencies, defect, vibration stresses.

Introduction. Numerous units of state-of-the-art machines are characterized by the presence of constructive regularity. First of all, this is true for the blade rows of turbine wheels characterized, as a rule, by a structural rotational symmetry (i.e., by a special type of regularity). However, due to the action of various technological factors, these systems are produced with inevitable deviations from the identity and periodicity of location of elements of the same type, i.e., blades in our case. These deviations are, in turn, responsible for the deviations in the elastic, inertial, and dissipative characteristics whose integral influence leads to the detuning of frequencies and damping characteristics of vibrations of similar elements in regular systems. The analysis of the results of theoretical and experimental investigations of the influence of the detuning of blade frequencies on the formation of vibrations of the blade row shows that the indicated detuning affects the fundamental properties of the spectra of natural vibrations and results in the appearance of the spread of amplitudes of the resonance vibration stresses [1–3].

Under the operating conditions, one or several similar elements of the investigated system may have defects in the form of fatigue cracks, nicks, etc., which, in fact, also lead to the violation of regularity. The analysis of the scientific and engineering literature shows that the available results of investigations deal, for the most part, with the study of the influence of defects on the regularities of vibrations of individual structural elements (e.g., rods, beams, shafts, plates, and blades) [4–7]. As to the best of our knowledge, the number of available publications devoted to the investigation of the influence of defects of this sort on the formation of vibrations of regular systems in the form of packets or blade rows of turbine wheel is fairly small [8–10]. Moreover, the works [8, 9] deal solely with numerical calculations. Some results of experimental investigations aimed at the evaluation of the influence of defects in the form open edge cracks and in the form of grooves on the frequencies and shapes of vibrations in a simple model of a regular system formed by two similar rodlike elements are presented in [10]. However, they were obtained for a broad range of depths of the groove and its fixed location along the length of the rod. Despite the small amount of the available data of investigations, their results reveal presence of a strong influence of defects on the formation of vibrations in regular systems. Therefore, the aim of the present work is to establish the regularities of the influence of two parameters of local defects (depth and location of the open crack) in the regular system on the range of eigenfrequencies of vibrations and the level of vibration stresses in elements of the same type.

Object of Investigations and Basic Concepts of the Experimental Procedure. By analogy with [10, 11], as the object of investigations, we choose specimens in the form of a tuning fork with prismatic rods regarded as a simple example of regular systems formed by two similar elements (subsystems) in modeling the open edge cracks

by the corresponding grooves. The design of the specimen (Fig. 1) and methodical approaches to its testing are similar to those described in [10]. The specimens were made of D16 aluminum alloy in the as-delivered condition. Its modulus of elasticity is equal to \( E = 0.71 \times 10^5 \) MPa and mass density to \( \rho = 2.8 \times 10^3 \) kg/m\(^3\) [12]. The length of the working part of the specimens \( L = 175 \) mm and the height \( h \) and width \( b \) of their cross section constituted 15 and 8 mm, respectively.

In the intact state, the specimen is strictly regular, i.e., the defects are absent and the eigenfrequencies of vibrations of the rods in the isolated state are identical.

A defect in the form of a rectangular groove of width \( c = 1 \) mm and depth \( a \) simulating an open edge crack was made in one rod of each of four tested specimens across its working part at a distance \( l \) from the root section. The depth of the groove \( a \) was measured with the help of an ICh-10 clock-type indicator mounted in a special device and varied from 0 to 8.3 mm. This corresponds to the following range of its relative values: \( \bar{a} = a/h = 0–0.56 \).

In what follows, the intact rod is marked by the subscript \( j = 1 \) and the damaged rod by the subscript \( j = 2 \).

To find the level of strains in the vicinity of the defect in one of the rods, the third specimen was additionally prepared at a relative distance \( \bar{L} = l/L = 0.5 \) from the restraint by resistance strain gauges \( T_3 \) on the working surface of the intact rod and \( T_4 \) on the working surface of the damaged rod opposite to the location of the groove.

**Experimental Results.** The experimental investigations of the chosen specimens aimed at finding the spectrum of eigenfrequencies of vibrations and the level of vibration stresses were carried out by changing both the depth of the groove and its location.

Prior to testing, according to the statement of the problem, the specimens were subjected to the adjustment of strict regularity, i.e., to guaranteeing the equality of the eigenfrequencies of vibrations \( f_j \) \((j = 1, 2)\) of the rods in the isolated state. This was realized as follows: It is well known that, in view of the fundamental properties of vibrations in the analyzed system, the in-phase mode of vibrations of the rods is the sole possible mode of vibrations in the case of strict regularity of the system and kinematic excitations. Moreover, the resonance frequency of vibrations in this mode \( f_0 \) coincides with the eigenfrequencies of the rods, i.e., the following equality is true: \( f_0 = f_1 = f_2 \). To attain the indicated state of the vibrating system in the course of the tests, we modified the elastic and inertial properties of the rods to guarantee the validity of the presented equality, which was confirmed by the indications of a frequency meter. Furthermore, the exact adjustment of regularity of the system was checked by analyzing the amplitude of stresses \( \sigma_0 \) in the root section of each rod deformed according to the first bending mode. The frequency of vibrations \( f_0 \) and the level of stresses \( \sigma_0 \) were accepted as basic and then used for the comparison of the corresponding characteristics of the system obtained as a result of violation of its regularity by the damaged second rod \((j = 2)\).

Prior to the analysis of the characteristics of vibrations of the investigated system in the presence of defects, we consider their influence on the eigenfrequency of vibrations of an isolated rod. To guarantee the required isolation of the rods operating as parts of a single system, we attach a weight to one of these rods whose mass guarantees a