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EXPERIMENTAL INVESTIGATION PROCEDURE OF THE VIBRATION CHARACTERISTICS OF THE STRUCTURAL ELEMENTS

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Abstract: *The experimental procedure and test bench for the investigation of the vibration characteristics of beam specimens are developed. The kinematic excitation of the structural elements is performed by translational motion of the electrodynamic vibrator coil. The parameters of the test bench allow one to maintain the specified vibrations in a wide range of variations of the excitation frequency and vibration amplitudes.*

Keywords: Forced vibrations, Fatigue crack, Beam specimen, Electrodynamic vibrator, Resonance vibrations.

1. Introduction

The reliable and trouble-free operation of machines and mechanisms is possible using the methods and means of vibration diagnostics. The main purpose of vibration diagnostics is to improve the reliability of objects during their operation phase, prevention of possible failures, etc. Diagnostic information can be obtained using numerical and analytical calculations. But their verification is made only by experimental methods (Matveev and Onishchenko, 2016).

The presence of fatigue crack in the structural element causes variations in the system rigidity due to the alternate opening-closing of its faces (breathing process) at the half-cycles of vibrations, which defines their nonlinearity, namely, the appearance of multiples harmonics in the spectrum of resonance vibrations, and excitation of non-linear resonance modes at the natural vibration frequency (super and subharmonic resonances). The spectrum of vibration amplitudes in these resonance modes consists of two dominant harmonics corresponding to the excitation frequency and the resonance frequency. The ratio of these harmonic amplitudes can be used as a vibrodiagnostic parameter of the presence of damage (Hiwarkar et al., 2012).

2. Test Bench for the Determination of the Vibration Characteristics of the Structural Elements

Figure 1 illustrates the experimental investigations on the determination of vibration characteristics of the specimens with fatigue cracks (Onishchenko et al., 2020), as well as the block diagram and general view.

Specimen 4 is rigidly fixed in clamp 1 on a solid plate, which is placed on rubber chambers 5 for insulation of the vibration system. Flexural vibrations of the specimen are induced by electrodynamic vibrator 2, its moving coil is fixed to the free end of the beam. The current in the moving vibrator coil is proportional to the generator voltage, which gives a harmonic signal. Thus, the vibrator force is harmonic and independent of the specimen vibrations.

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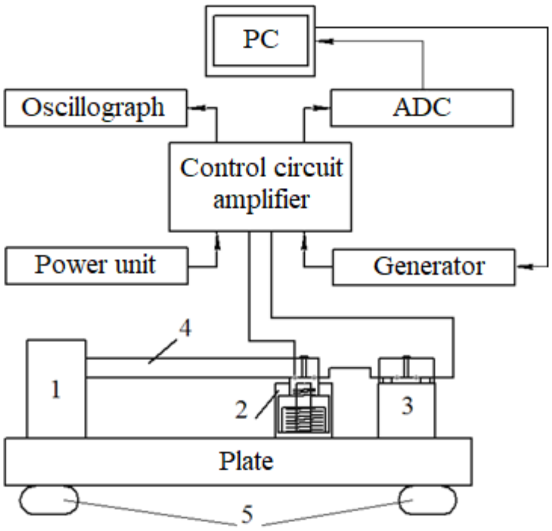
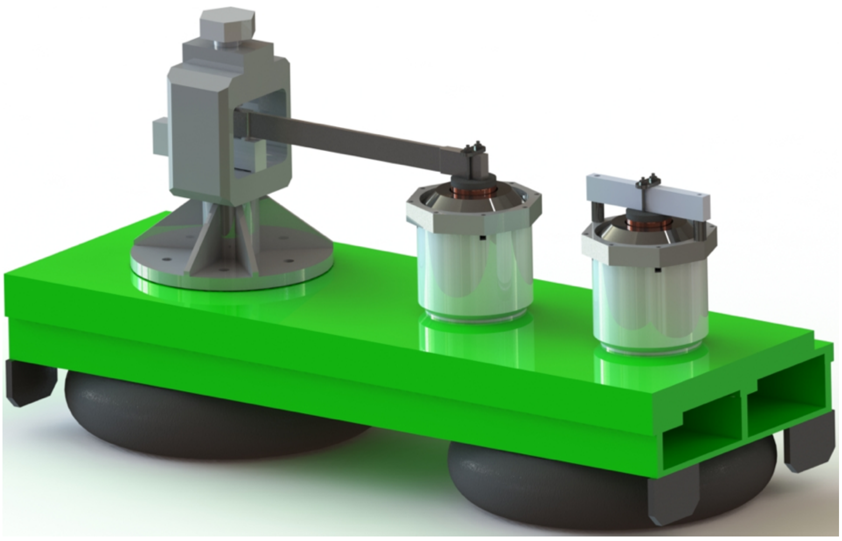


a

1 –clamp; 2, 3 – electrodynamic vibrators; 4 – specimen with a crack; 5 – rubber chambers



b

Fig. 1. *– Block diagram (a) and general view (b) of the experimental setup for the determination of the vibration characteristics of the beam specimens with damage at super- and subharmonic resonances.*

3. Procedure of the Experimental Determination of the Vibrodiagnostic Vibration Parameters

The procedure for measuring the characteristics of the forced vibrations is as follows. A current is applied to two electrodynamic vibrators, which are series-connected (Fig. 1, *a*, 2, and 3). The coil of the first one is attached to the specimen and provides its vibrations. At the same time, the coil of the second vibrator is fixed motionless. An analog-to-digital converter (ADC) is used to measure the electromotive force (EMF) voltage of the vibrator coil movement U_{EMF} and its drop across a resistor U_R.

EMF voltage of the coil movement of the vibrator is proportional to its motion V, as well as its displacement rate of the specimen end:

$$U_{EMF} = B_в \cdot l_к \cdot V \tag{1}$$

Where B_B is the induction in the vibrator gap, l_k is the conductor length of the moving coil in the given gap.

The vibration velocity of the coil can be easily determined using amplitude A and frequency of its vibrations f:

$$V = 2\pi \cdot f \cdot A \tag{2}$$

As the resistor *Re* is series-connected with the coil, the voltage drop is defined as $U_R = I_k Re$, where I_k is the current force in the moving coil. By measuring U_R, one can determine the force value of the vibrator:

$$F = B_в \cdot l_к \cdot \frac{U_R}{Re} \quad (3)$$

4. Results of Investigations

The investigation of vibrations of the specimen beam was performed (Fig. 2). As an example, Fig. 3a illustrates the results of the investigations for the undamaged specimen (red line) and with a fatigue crack (black line). It can be seen from the data that in the case of the undamaged specimen excitation, there is a harmonic corresponding to the principal resonance frequency. At the same time, when the specimen with a fatigue crack is excited, the harmonic at the principal resonance is observed at a lower frequency than for the specimen without damage. In addition, harmonics at a double frequency from the principal resonance are observed on the vibration amplitude spectrum, which indicates the nonlinearity of the system caused by the presence of fatigue crack in the specimen. The indicated experimental results are in qualitative agreement with the investigations obtained in (Sinenko and Zinkovskii, 2015, Kruts, 2018). Figure 3b shows the amplitude of damped vibrations of the specimen, which allows one to determine the dissipative properties of the material under investigation.

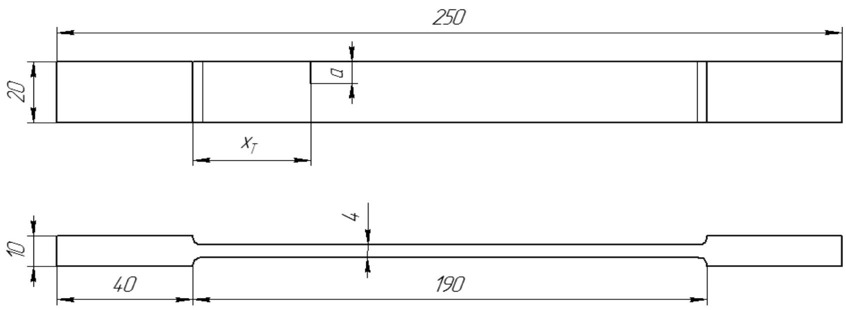
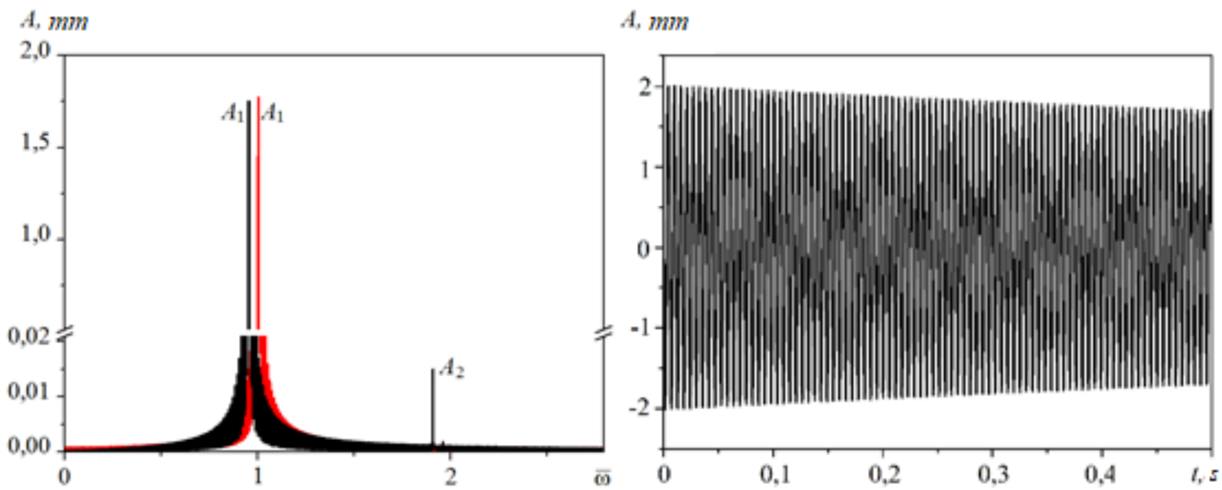


Fig. 2. Beam specimen with a breathing crack



a *b*

Fig. 3. – Results of the investigations on the beam specimen: spectrum of its vibration amplitudes at the principal resonance of the undamaged beam specimen (red line) and with a fatigue crack (black line) (a) and amplitude of damped vibrations of the beam specimen for the determination of its dissipative properties (b)

5. Conclusions

The test bench, which was developed to excite the forced flexural vibrations of the beam specimens with fatigue cracks, and the experimental procedure allow one to determine the following vibration characteristics:

•natural and resonance vibration frequencies;

•dependencies of displacement, velocity, and acceleration (depending on time) of the beam free end, as well as the corresponding spectra of the vibration amplitudes;

•vibration decrement.

Due to the technological solutions, the setup has a low level of nonlinearity in the driving force spectrum, which allows one to determine the effect of fatigue cracking on the vibration characteristics of beam-shaped structural elements when the vibrations are excited at the frequency of principal, super- and subharmonic resonances. The obtained results make it possible to develop new and improve the existing methods of vibration control during production and damage vibrodiagnostics of the structural elements.

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