

Research methodology based on the idea of the limiting transition of damping properties of structures vibrating in the "air" medium using a laser vibrometer

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Abstract

Purpose: This work is devoted to experimental studies of a cantilever beam, the development of a technique for measuring vibrations in a hydroelastic medium based on measurements in an "air" medium and the results of a comparative analysis of the amplitude-frequency characteristics of a cantilever obtained in an "air" medium.

Design/methodology/approach: The experimental installation was designed, developed and manufactured on the basis of the Far Eastern experimental basin of KnASU. It is designed to determine the parameters of free hydroelastic vibrations of a mechanical system with a point mass at the free end, it allows you to determine the amplitude-frequency characteristics. The work uses four models with different sail areas. To take readings in the experiments, we used the Polytec vibrometer software (Polytec High Speed Laser Vibrometer HSV2001). Experimental data processing and graphing were carried out using the Microsoft Excel program.

Findings: As a result of the experiments carried out, an assessment was made of the error of the obtained experimental data between the direct and mediated determination of the vibration parameters of the structure. The graphs for estimating periods with and without a flag have been obtained.

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Originality/value: The technique is original. Its originality lies in the use of a new idea of the passage to the limit and in performing experiments based on a vibrometer (Polytec High Speed Laser Vibrometer HSV2001). The results obtained on the basis of experimental studies are also original. The technique was created for practical use and allows one to determine the damping characteristics of systems vibrating in various liquids and consisting of various materials.

Key words vibrometer, experimental setup, hydroelastic vibrations, am-amplitude-frequency characteristics, mechanical systems

JEL Code C02

1 Introduction

As the size and speed of the ship increases, the vibration of its sides increases. This becomes a big problem that needs to be solved in the design and construction of ships. Excessive vibration of the ship should be avoided for the sake of passenger comfort and crew capacity (Iwer et al., 2001). In addition to undesirable effects on humans, excessive ship vibration can lead to fatigue failure of local structural elements or malfunction of machinery and equipment (American Bureau of Shipping, 2006).

The experimental setup was developed on the basis of the far Eastern experimental pool of KnASU and is designed to determine the parameters of free hydroelastic vibrations of a mechanical system with a current mass at the free end. Figure 1 schematically shows an experimental setup. It is designed to determine the resistance parameters for free hydroelastic vibrations of the console, with a point mass at the free end. This setup allows you to calculate the amplitude-frequency characteristics, damping coefficients, and resistance coefficients of the external and internal media of an oscillating system.

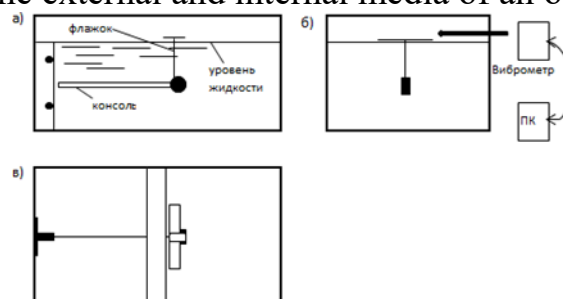


Figure 1 – Experimental setup diagram:
(a) – side view; (б) – front view; (в) – top view

Source: developed and compiled by the authors.

Brief description of the installation: the left end of the beam is rigidly pinched, the right end is free and has a concentrated mass in the form of a load. The beam makes oscillatory movements in the direction of the y-axis.

Figure 2 shows a 3D view of the experimental setup.

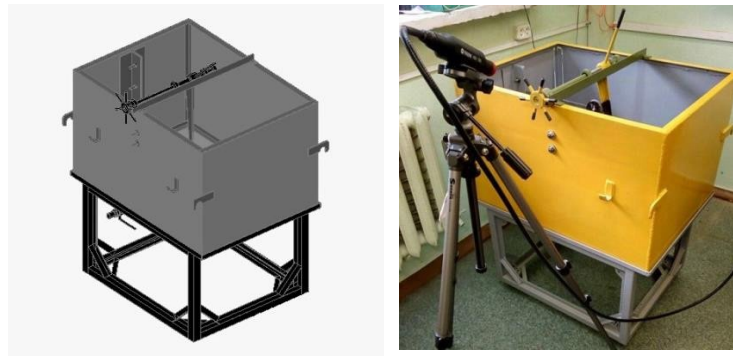


Figure 2 – experimental setup

(a) - 3D view; (b) – photo of the experimental setup

Source: developed and compiled by the authors.

For convenience of consideration, the experimental setup was conditionally divided into four "separate sets of parts" such as:

- the bowl of the pool;
- motor platoon of the maximum deflection of the beam;
- stand for installation;
- console.

Let's look at each "complex" separately in more detail.

The pool bowl (figure 3) is designed to create a working environment in which research will be performed.

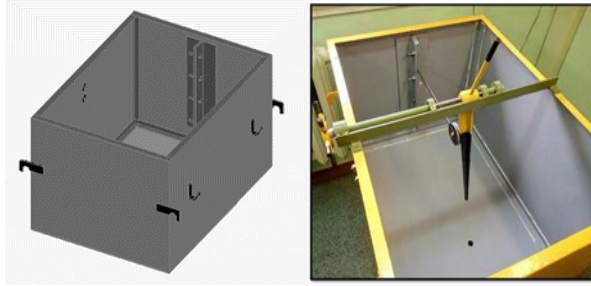


Figure 3 – pool bowl: (a) - 3D view; (b) – take photos

Source: developed and compiled by the authors.

A pool bowl consists of individual parts such as:

- welded steel sheets reinforced with corners;
- pinching device that attaches the console;
- stops for manual carrying;
- a drain device designed to remove "waste media" from the experimental

installation.

The platoon drive (figure 4) of the maximum beam deflection is designed to deflect the system from the equilibrium position.

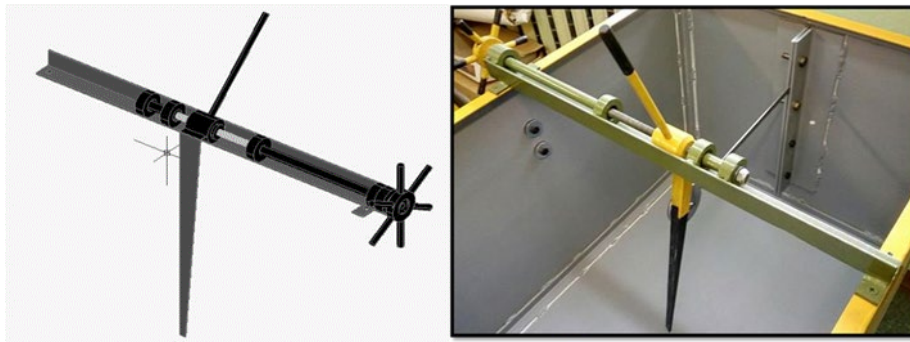


Figure 4 – maximum beam deflection platoon drive

(a) – 3D view; (b) photograph of the platoon actuator maximum deflection of the beam

Source: developed and compiled by the authors.

This device consists of individual parts, such as:

- support corner;
- two thrust bearings;
- three support bearings;
- regulator of deviation of the beam;
- shaft for the beam deflection regulator;
- trigger.

The installation stand (figure 5) is designed to hold the entire experimental installation in place.



Figure 5 – Installation stand

(a) – 3D view; (b) – photo of the installation stand

Source: developed and compiled by the authors.

It consists of the following details:

- profile beams, welded together and reinforced with corners;
- welded together in the corners to hold the pool in a stationary state during operation.

The console is necessary for determining the parameters of free hydroelastic vibrations of a mechanical system with a point mass at the free end.

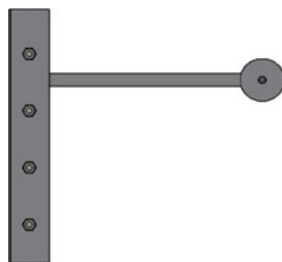


Figure 6 – 3D view of the cantilever beam

Source: developed and compiled by the authors.

The console consists of:

- a beam rigidly secured by a pinching device;
- a model that gives the console a point mass.

2 Materials and method

Performing measurements of the console's amplitude-frequency characteristics. Measurement of the amplitude-frequency characteristics on the model and on the flag is performed in the program "Polytec vibrometer software". We use four models with different windage areas (figure 7).

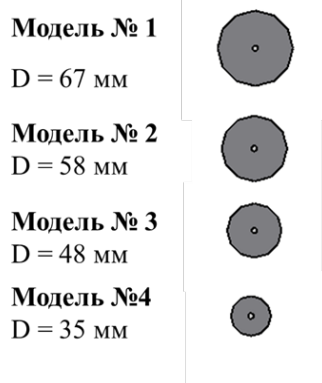


Figure 7 – models with different windage areas

Source: developed and compiled by the authors.

When the structure is located in environments such as water, diesel fuel, engine oil, and other liquids, it is difficult to perform vibration measurements using laser devices. The solution to this problem is to use a special marker-a flask placed at a certain distance from the object. In this case, measurements are made

using the flag and the calculated coefficient of influence of the flag determines the actual values. To reduce the measurement error, the flag is attached to the structure under study using a rigid connection – a steel rod.

To determine the coefficient of influence of the flag in this work, studies were conducted on measuring vibration and on the design itself in the "air" environment and on the flag. Based on a comparison of the results obtained, we can conclude that the proposed method for measuring vibration of structures in liquid media is correct.

After taking readings of the amplitude-frequency characteristics on the model and on the checkbox, the received data is processed using the "Microsoft Excel" program. Based on the data obtained, graphs are plotted for comparing the amplitude-frequency characteristics of the model and the flag.

3 Results

Performing measurements of the amplitude-frequency characteristics on a console with a diameter of the attached mass of 67 mm. After performing measurements in the program "Polytec vibrometer software", we go to the averaging of data from ten graphs (console without a check box) and get the averaged data, which we use to build a graph. Figure 8 shows the graph of averaged data for the console's amplitude-frequency characteristics without the check box.

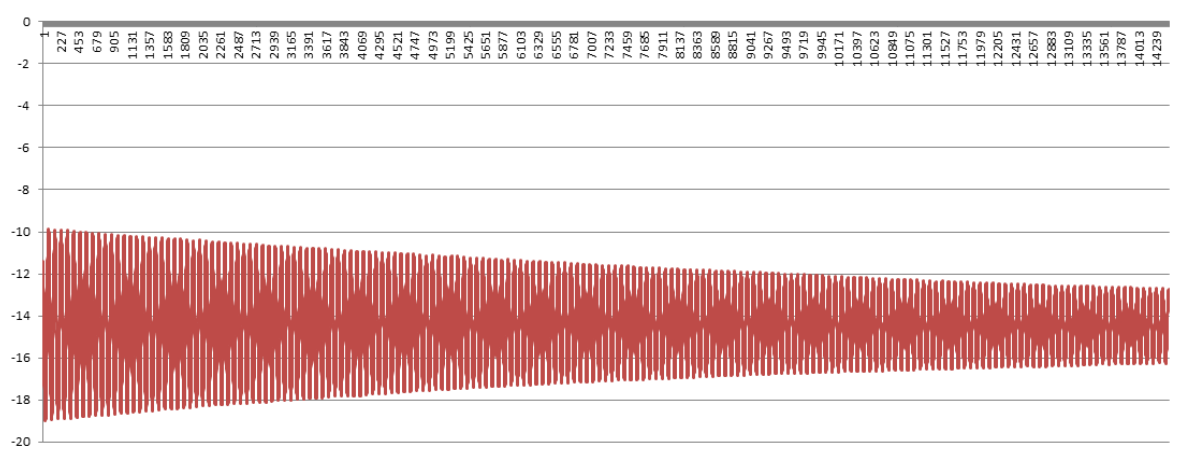


Figure 8 – averaged amplitude-frequency data

console characteristics without a check box (for the middle of the mass)

Source: developed and compiled by the authors.

A graph of the averaged data of the console's amplitude-frequency characteristics with a check box is shown in figure 9.

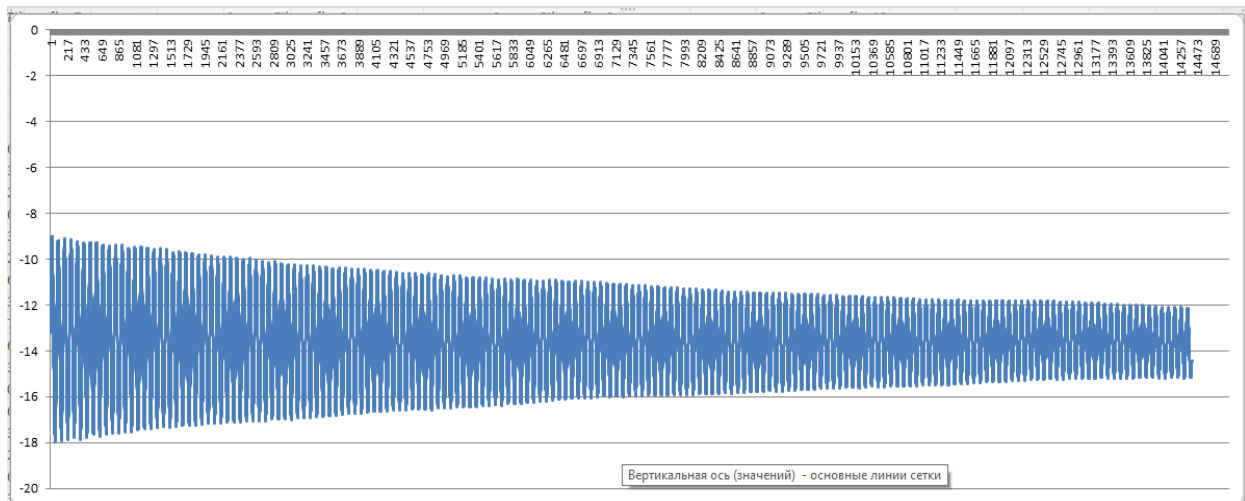


Figure 9 – averaged amplitude-frequency data

console properties with a flag (for the middle of the flag)

Source: developed and compiled by the authors.

The resulting graphs of the average values of the amplitude-frequency characteristics of the console with and without a flag are superimposed on each other to identify visually and in detail visible differences between the graphs. Figure 10 shows superimposed graphs.

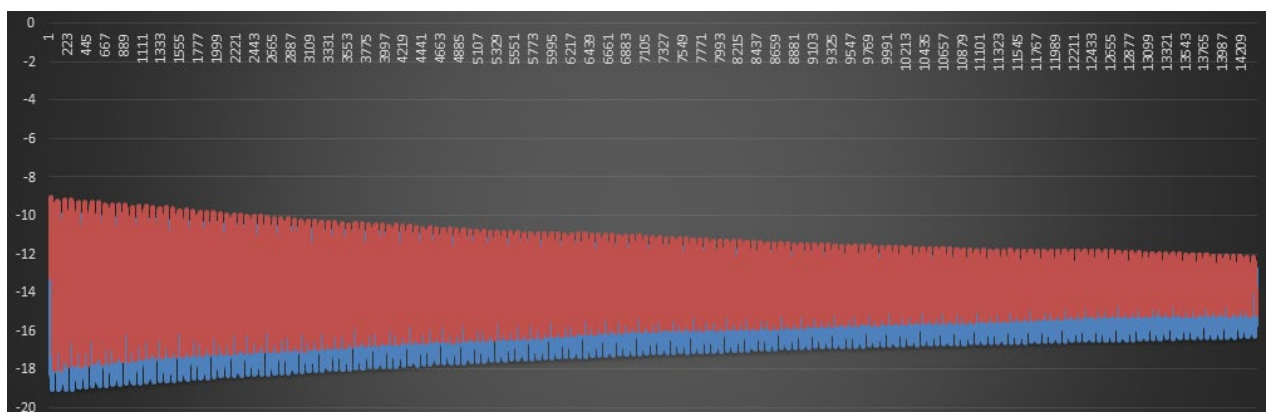


Figure 10 – graphs of the average values of the amplitude-frequency console settings with a flag (red)

For a clear view of the difference between measurements with or without a flag, select a separate part with a well-established oscillation period from the graph shown in figure 10. This part of the graph is shown in figure 11.

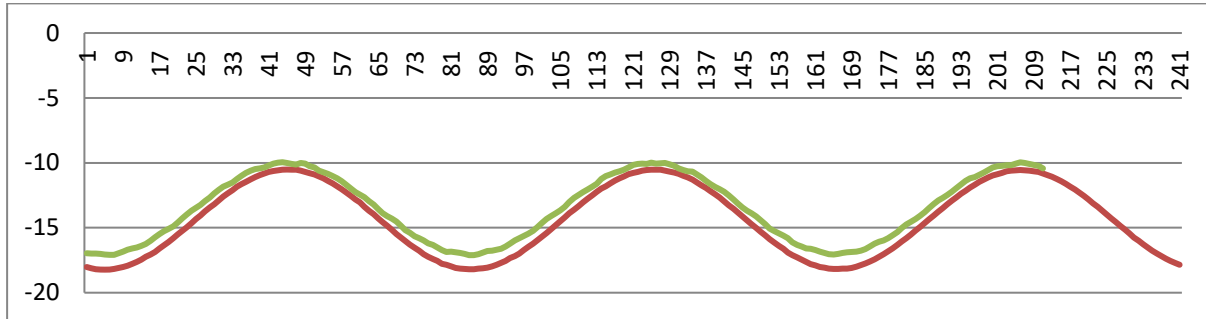


Figure 11 – Part of the chart with a well-established oscillation period:

red – for the flag, green – for the mass

(time interval from 9.5 s to 10.5 s)

Source: developed and compiled by the authors.

The resulting graph shows that changes in the amplitude-frequency characteristics when performing measurements (laser on the flag and on the mass) are insignificant and make up an error of less than 5%. As in the method described above, measurements of amplitude-frequency characteristics were performed on the console and with other diameters of the attached mass: 58 mm, 48 mm and 35 mm. According to the results obtained, as can be seen from the graphs obtained, it can be stated that the changes in the amplitude-frequency characteristics when performing measurements (laser on the flag and on the mass) are insignificant and make up an error of less than 5%.

Construction of calculated graphs of the beam oscillation period at the 10th, 20th, and 30th seconds. To get all the data we are interested in, we calculate the calculation of the beam oscillation periods for each second of the experiment and determine where the beam oscillations are stable.

Calculated graphs of the beam oscillation periods at the 10th, 20th, and 30th seconds of measurements are shown in figures 12, 13, and 14.

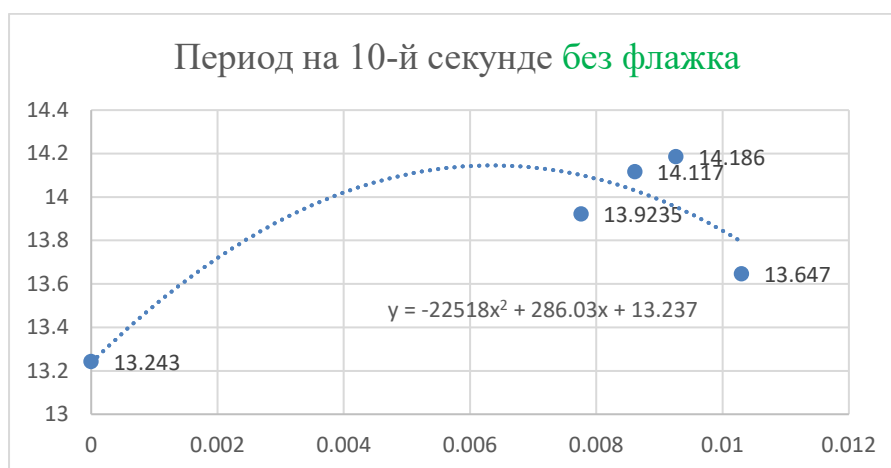
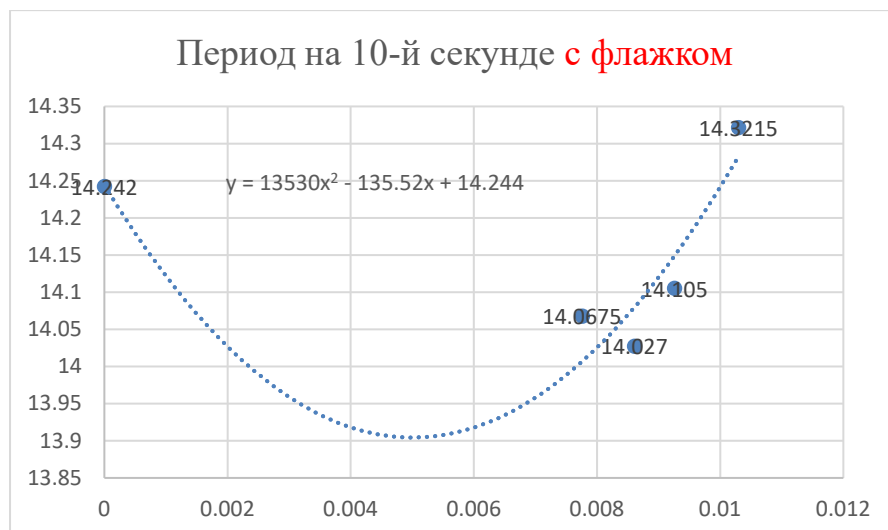
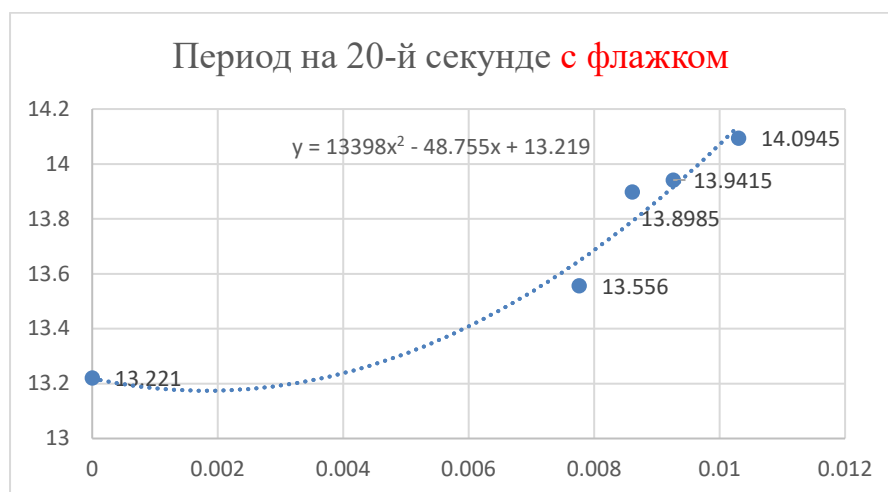


Figure 12 – calculated graphs of the beam oscillation Period
at the 10th second of measurement

Source: developed and compiled by the authors.



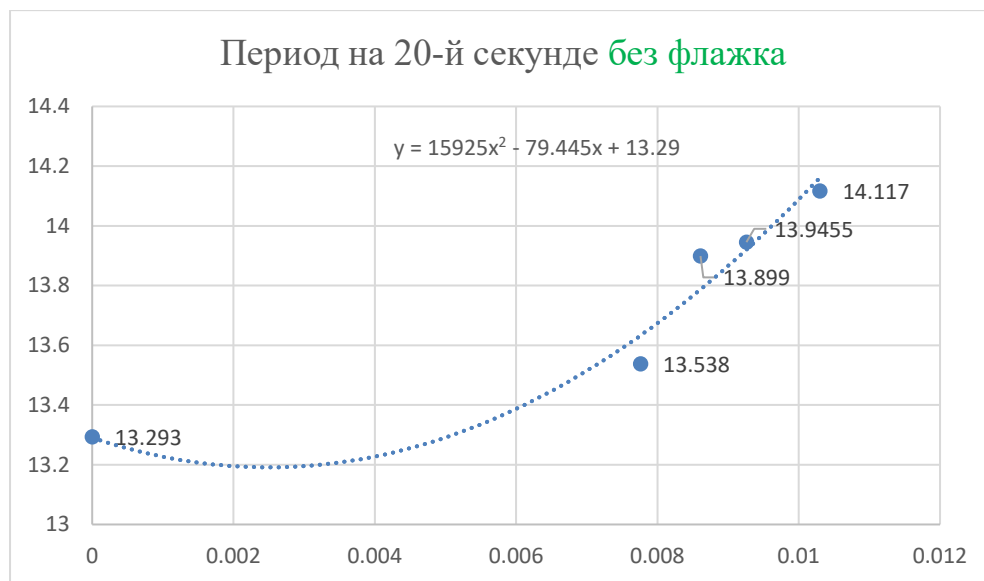
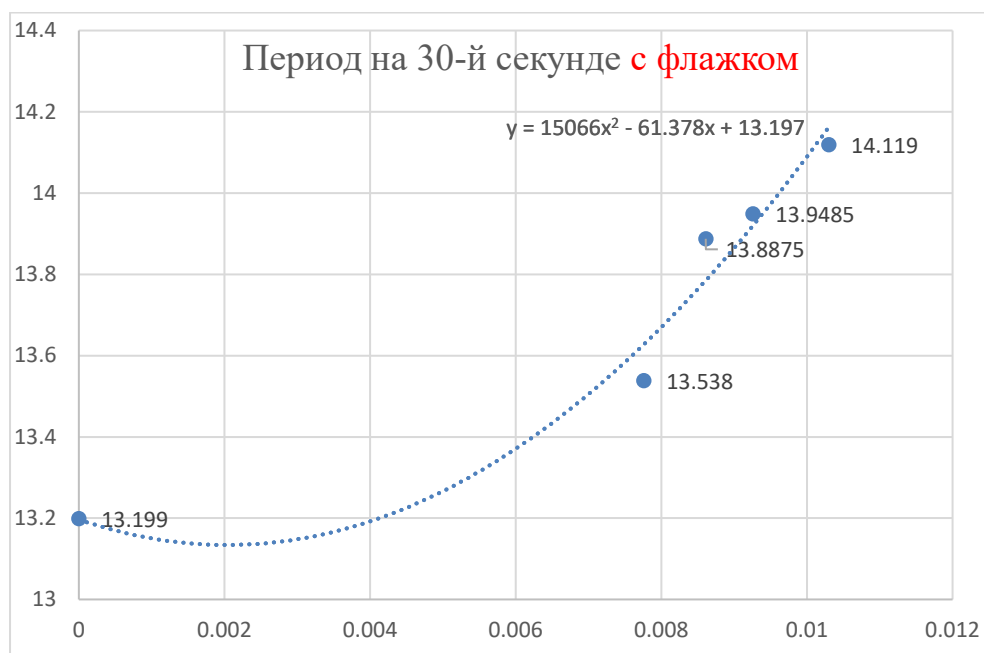


Figure 12 – calculated graphs of the beam oscillation Period
at the 20th second of measurement

Source: developed and compiled by the authors.



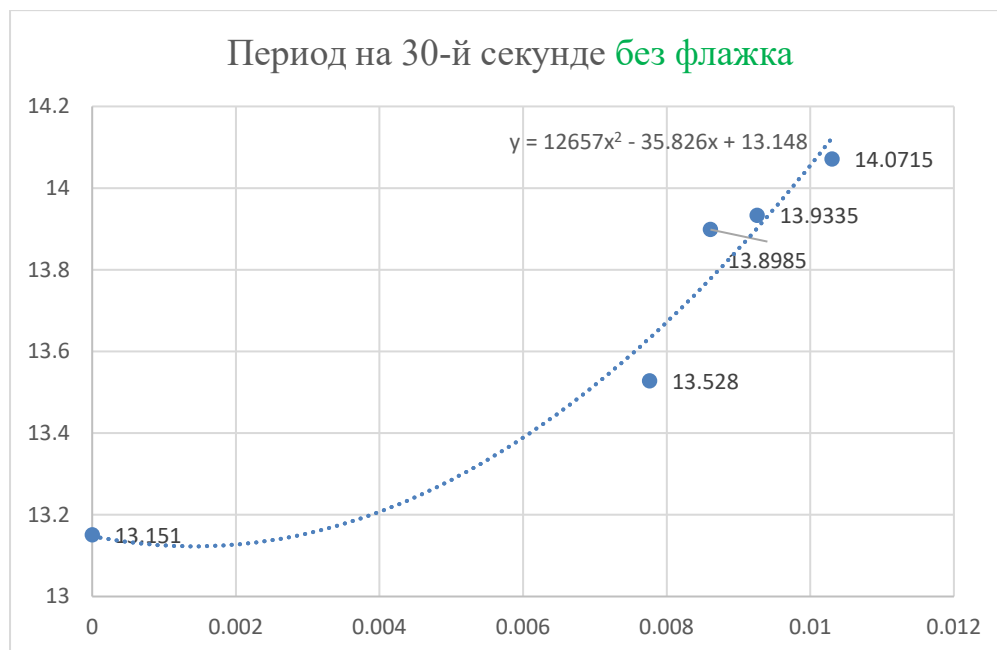


Figure 12 – calculated graphs of the beam oscillation Period
at the 10th second of measurement

Source: developed and compiled by the authors.

Conclusion

1. In this work, using experimental data obtained at the installation, graphs of the amplitude-frequency characteristics of the cantilever beam were constructed using the program "Polytec vibrometer software". The results of comparison of graphs obtained on the basis of measurements for the model and for the flag are presented. A comparative analysis of all the amplitude-frequency characteristics of the cantilever beam obtained in the "air" medium is performed.
2. The transition point for the period (T) is 13.229 seconds.

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