Improving the methodology for assessing the technical condition of equipment during the transportation of energy carrier in energy systems and complexes

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Abstract. The stable and uninterrupted work of the energy sector enterprises largely determines the economic development of the country. At the same time, the reliability of energy systems and complexes depends on the technical condition of the energy transportation equipment. In this regard, there is an urgent need to monitor the technical condition of the equipment. Currently, there are various types of non-destructive testing used for diagnostics, but none of them is universal, and many of them only allow to find defects of a certain type. In this connection, there is a topical issue of improving the methods for assessing the technical condition of equipment during the transportation of energy carriers in energy systems and complexes. This paper presents an information and diagnostic complex that implements the proposed technical solution and tests the methodology.

1 Introduction

Energy sector is a basic sector of the national economy. Reliable work of energy sector enterprises is a guarantee of the country's energy security and its stable economic growth.

However, at the moment, about 20% of all capacities at the enterprises of the energy industry is produced on end-of-life equipment, while the renewal of energy capacities and their major repairs are produced in irrational proportions. The growth of production capacity, a large degree of wear of equipment, as well as the wasteful energy consumption, all these factors introduce the energy industry to an area of heightened risk, technological failures, accidents, making the energy supply system less reliable [1].

The decision of these and other problems in the fuel-and-energy complex becomes essential. In this regard, the Federal Law No. 261-FZ “On Energy Saving and Improving Energy Efficiency and Amending Certain Legislative Acts of the Russian Federation” was adopted by the Government of the Russian Federation and the State Duma in November 23, 2009. Also the Government of the Russian Federation has adopted the order No. 1715-r “Energy Strategy of Russia for the Period up to 2030 (ES-2030)” in November 13, 2009 [2-6].

2 Formulation of the problem

To ensure reliable work of the energy system and, as a result, to ensure uninterrupted supply of thermal energy to consumers, special attention should be paid to the technical condition of the energy transportation equipment in energy systems and complexes [7, 8].

The main reasons for the high requirements for reliability and safety of heat and power equipment are human casualties and heavy financial and environmental damage in case of accidents caused by the destruction of energy equipment, buildings and constructions, as well as the termination of the production process for a long time [9,10].

All this circumstances make it necessary to pay increased attention to the diagnosis and monitoring of the technical condition of energy equipment. Technical diagnostics is carried out regularly, and the methods and diagnostic tools currently in use make it possible to accurately determine the type of defect, its size and location. [11,12]. However, in practice, there are several diagnostic methods that are used to determine the technical condition of an object, but each of these methods allows to detect defects of a certain type. The scope of work on technical diagnostics and the type of the applied means of control depend on the design of the equipment, its features and its service life. [13-16].

In this regard, it is very important to improve the methodology for assessing the technical condition of equipment during the transportation of energy carriers in energy systems and complexes, which is the purpose of this work.

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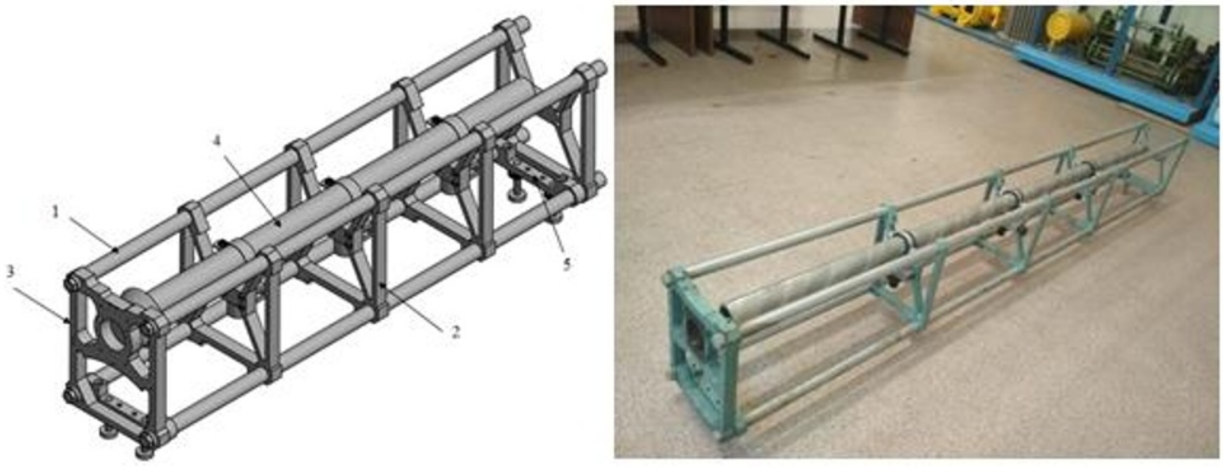

Fig. 1. Information and diagnostic complex: 1 – slideway; 2 – prop with clamp; 3 – prop with acoustic emitter; 4 – the investigated pipe; 5 – base with legs.

3 Information and diagnostic complex

An information and diagnostic complex (IDC) has developed to improve the methods of diagnosis of energy equipment.

The IDC (figure 1) consists of: the system of supports with clamps, which attached the pipeline selected as the object of control, the complex also includes an excitation system consisting of an excitation device shown in figure 2, and a registration system consisting of a sensing element and an analog-to-digital converter connected to a personal computer by electric communication.

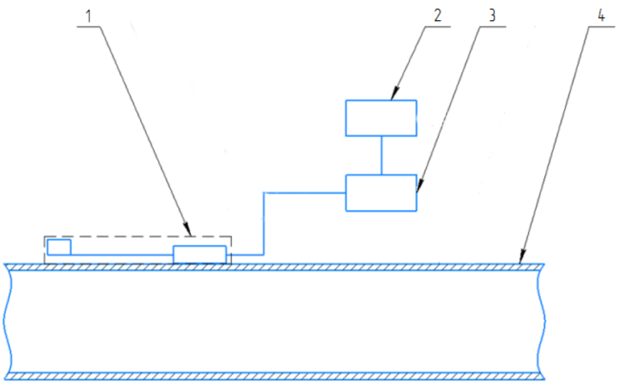

Fig. 2. Excitation device: 1 – inertial resonator, 2 – personal computer; 3 – digital-to-analog converter; 4 – the investigated pipe.

The principle of work of the IDC is as follows. The excitation device is attached to the pipeline, then with the help of a personal computer and digital-analog converter, this device is activated, it causes the vibration in the wall of the pipeline under study, then with the help of a sensing element made in the form of a microphone, the vibration parameters of the wall are measured, and then the obtained information is received to the personal computer through the analog-digital converter for registration and further analysis.

To control the vibration effect on the pipeline under study, as well as to collect, store and process signals coming from the microphone, a computer program "Condition monitoring system" was developed in LabVIEW [17,18]. Figure 3 shows the "Generation" program panel, in which the rotational speed of the inertial resonator can be controlled and adjusted. Figure 4 shows the “Registration” program panel, in which the signals from the microphone are recorded and converted to a spectrum for further analysis.

Fig. 3. “Generation” program panel.

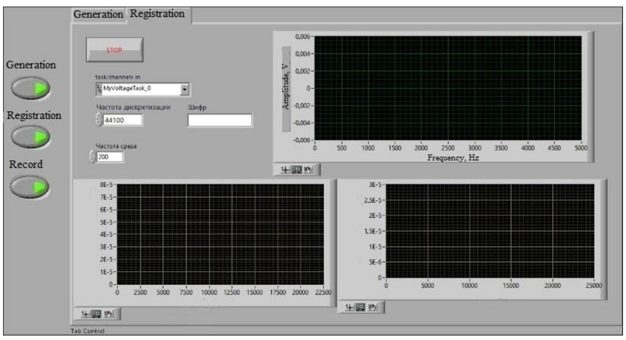

Fig. 4. “Registration” program panel.

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4 Determination of natural frequencies of oscillations of the IDC for monitoring the technical condition of equipment

As a result of the study, the modes of oscillations of the IDC are determined. When analyzing the results of the modal calculation, it is necessary to take into account that the form of free oscillations was calculated in relative units, and it did not allow determining absolute displacements.

The results are presented in table 1.

Table 1. Calculation results.

Oscillation mode number	Frequency Hz.	Oscillation mode number	Frequency Hz.
1	92.848	26	1014.3
2	142.05	27	1028.3
3	166.21	28	1063.1
4	173.32	29	1119.7
5	188.1	30	1140.7
6	262.38	31	1175
7	322.11	32	1220.8
8	337.9	33	1262.6
9	391.28	34	1268.2
10	424.07	35	1284.8
11	483.53	36	1325.8
12	544.85	37	1331.4
13	574.89	38	1396.9
14	622.84	39	1424
15	738.09	40	1438.6
16	742.57	41	1441.5
17	749.35	42	1456.6
18	774.17	43	1484.8
19	828.85	44	1502.7
20	849.66	45	1541.3
21	876.57	46	1555.6
22	880.31	47	1609.1
23	921.44	48	1616
24	948.73	49	1638.6
25	955.44	50	1661.7

The oscillation mode shape of the fifteenth mode of the installation under study at a frequency of 738.09 Hz is presented in figure 5.

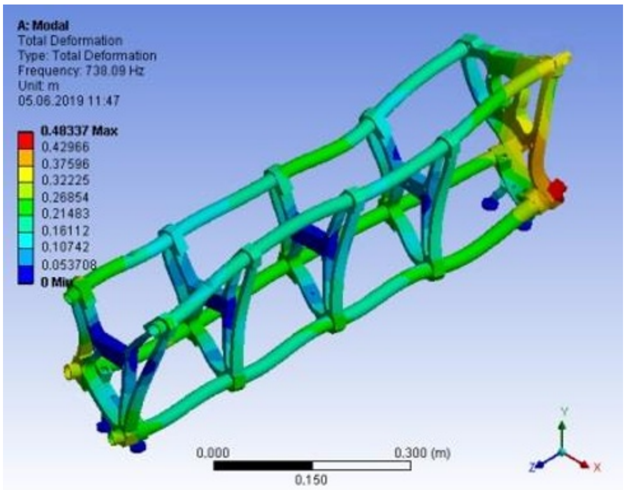

Fig. 5. Oscillation mode shape at frequency 738.09 Hz.

5 Laboratory tests

During the experiment, an inertial resonator with a rotation frequency of 15,000 rpm and an operating voltage of 3V was used to excite oscillations in the wall of the pipeline under study. Adjusting the rotational speed of the inertial resonator motor is implemented on the Arduino Uno electronic platform.

The generated frequencies were recorded using a microphone. Figures 6 and 7 show photographs of the laboratory stand.

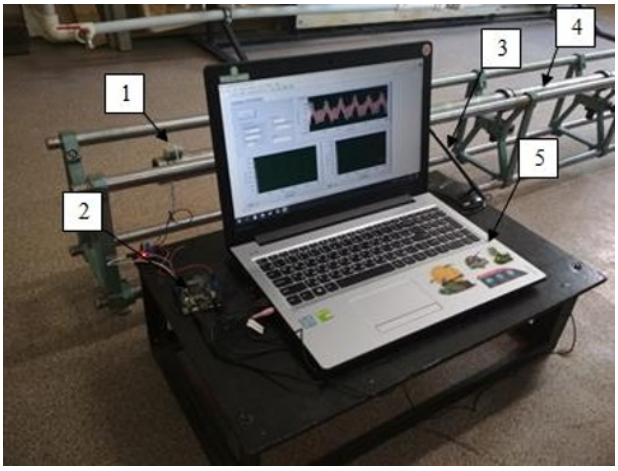

Fig. 6. The laboratory stand: 1 – inertial resonator; 2 – Arduino Uno Board; 3 – microphone; 4 – the investigated pipe; 5 – personal computer.

Fig. 7. Photograph of the laboratory stand.

The initial frequency of rotation of the inertial resonator is 100 Hz, the measurement step is 10 Hz, after 250 Hz, the measurement step is 5 Hz. Static and random error was 10%.

On the graphs, the amplitude in mV is plotted on the vertical axis, and the frequency in Hz on the horizontal axis.

The measurement results at some frequencies are presented in figures 8–13.

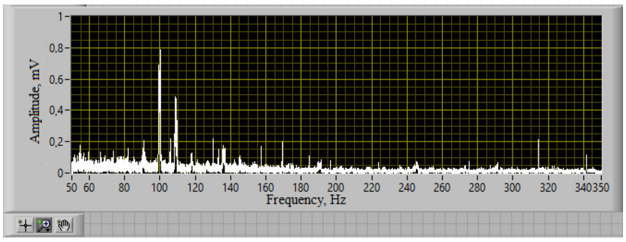

Fig. 8. Excitation frequency is 100 Hz.

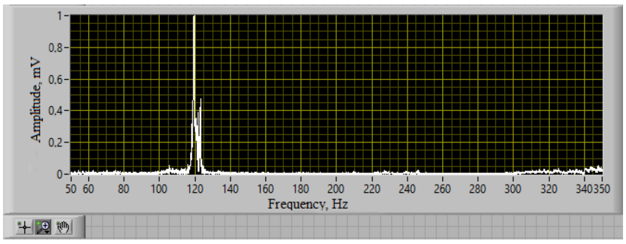

Fig. 9. Excitation frequency is 120 Hz.

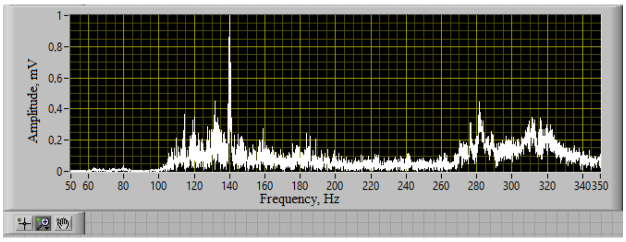

Fig. 10. Excitation frequency is 140 Hz.

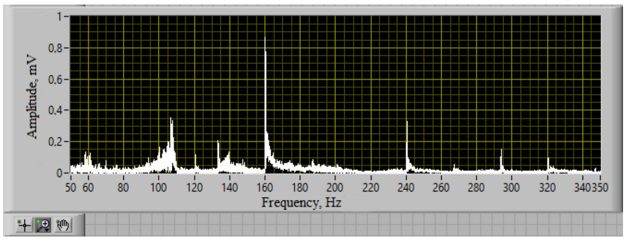

Fig. 11. Excitation frequency is 160 Hz.

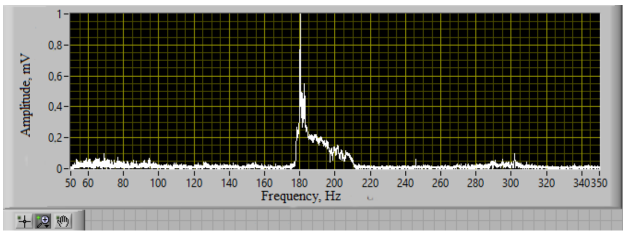

Fig. 12. Excitation frequency is 180 Hz.

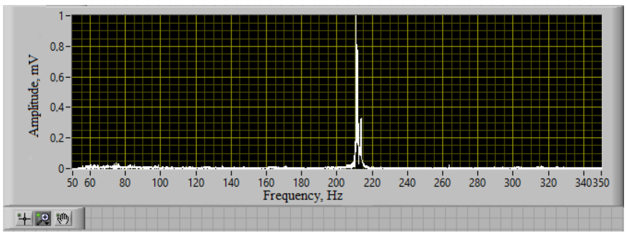

Fig. 13. Excitation frequency is 210 Hz.

6 Conclusion

Analysis of the calculation results in the ANSYS software package and experimental data shows that the main modes of pipeline oscillations coincide with an average deviation of 3%. The proposed method provides high accuracy of the assessment of the technical condition of equipment during the transportation of energy carriers in energy systems and complexes.

The developed technique is applicable in combination with other methods of non-destructive testing to improve the efficiency and reliability of the assessment of technical condition of the equipment

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