International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

September 2023 | Issue 56 | Volume 15 | Number 3 | Pages 25-33

DEVELOPMENT OF A SEISMIC RESISTANCE TEST BENCH FOR PIPELINE FITTINGS

A.P. Titova [1] A.M. Kerimov [1] A.K. Lampezhev [1] N.V. Dmitrichenko [2]

1. Institute of Design and Technology Informatics, Russian Academy of Sciences, Moscow, Russia
titova_ap@bk.ru, kerimov.abdulmejid@mail.ru, abas.lampezhev@mail.ru
2. LLC Carbon Materials, Vsevolozhsky District, St. Petersburg, Russia, natalia.dmitrichenko@bk.ru

Abstract- Ensuring industrial safety is a priority task in designing pipelines for critical technical facilities. Butterfly check valves are a type of pipeline fittings that exclude accidents associated with the reverse flow of the working fluid. During operation, butterfly check valves are subjected to various loads that affect the tightness and integrity of their design, which in turn affects the entire piping system. In this regard, development of pipeline fittings requires a number of criteria that determine the performance of the structure, vibration resistance and vibration strength are some of these criteria. Appropriate tests are required to confirm the structure reliability and performance according to these criteria. To determine seismic resistance and reliability in butterfly valves, it is important that the test results are reliable and have acceptable accuracy, since these characteristics play a key role in maintaining the long-term performance and trouble-free operation of the structure. Vibration tests are conducted to determine the parameters related to the seismic stability of the gates; and seismic benches are required to obtain accurate parameters and characteristics in the item under study. The specifics of the tested facilities may lead to the need to develop specialized benches specifically for these tests. In particular, this research aims to develop such a bench for testing the seismic resistance of butterfly check valves. Pursuant to the research, the device structure was designed and described; the desktop response to seismic impact and the stress-strain state of the bench were studied.

Keywords: Butterfly Check Valve, Pipeline Fittings, Mathematical Modeling, Finite Element Method, Stress-Strain State, Hydraulic Tests, Process Test Facility.

1. INTRODUCTION

Currently, the scope of pipelines is very large. Pipeline systems have found their application in many industries and apply to all areas of human activity: chemical, gas and oil production, nuclear industry, transport, metallurgy, and housing and communal services [1, 2]. Pipe fittings are devices installed in pipeline systems designed to control the working fluid flows by shutting off the supply, changing the flow direction, regulating parameters, mixing or separating the fluid [3]. Depending on the functional purpose, fittings are divided into different types [4, 5].

Fittings are used to transport water of various temperatures, saturated and superheated steam, chemical media, including aggressive ones, liquid metals and molten salts, gases of various aggregate states, slurry mixtures, etc. [6-8]. The pressure of working fluids can reach values up to hundreds of atmospheres at temperatures from close to absolute zero to thousands of degrees [9]. To maintain stable operation of pipeline systems, fittings must maintain deep vacuum in the system, excess pressure, and the alternate these parameters [10]. Therefore, the constant and safe functioning of pipeline fittings is significant for the efficient operation of the entire technical system [11].

Considering the operating conditions of the device and ensuring the reliability and durability of the structure are the most important tasks in the production of pipeline fittings [12]. These indicators, in turn, represent the ability of the structure to maintain tightness and performance throughout the service life [13]. Valves that ensure tightness and prevent changes in the fluid flow direction are the most important types in pipeline fittings [14, 15]. They are exposed to the greatest impact during the operation of pipelines [16-19]. The earthquake-caused seismic impact is one of the external factors that lead to the destruction of the facilities [20-21].

Butterfly check valves can be monitored using various numerical methods [22-25]. Vibration tests are used to control the quality and reliability of pipeline units [26-28]. Vibration tests make it possible to obtain the following properties of the item under study: assessment of reliability, selectivity and durability, material fatigue characteristics, durability and vibration loading [29]. However, it is required to conduct real vibration tests for confirming the calculated results and obtaining updated data, during which tests the main operational properties of the facility are determined. In this regard, this paper considers the issues of developing a new design of a measuring seismic bench for testing check valves.

2. LITERATURE REVIEW AND ANALYSIS

Various numerical methods are used to check the properties of valves under study. Current methods for comparative analysis are given in Table 1. Based on the analysis of the above studies, a solution was proposed to develop a new design of a measuring seismic bench to improve the accuracy and reliability of the measured parameters in butterfly valves.

Table 1. Results of the comparative analysis

Ref.	Research details
[18]	This research investigated the sealing failure mechanism in pipeline fittings as a result of fretting fatigue and vibration, and considered the impact of torque and pre-tightening torque on fretting fatigue behavior. Accelerated tests showed that a decrease in torque leads to an increase in fretting fatigue, which in turn leads to sealing failure of pipeline fittings. Within the framework of these studies, an electromagnetic shaker was used.
[19]	This research aims to reduce vibrations in liquid conveying piping systems. The authors propose a method for optimizing globally the shape and locations of rigid hangers for a 3D piping system to avoid resonance. The results show that shape optimization increases the seismic resistance of the piping system. This research presents a systematic method for global optimization design of three-dimensional piping systems.
[20]	This article considered the seismic margins of piping systems with a ratcheting mechanism, and presented a method for assessing seismic resistance. It was experimentally proved that under the action of a dynamic reverse load, the ratcheting mechanism is destroyed, which in turn leads to the failure of the entire system. The ratcheting mechanism was evaluated by a numerical method, which was confirmed by tests on a vibrating table. Thus, it can be concluded that the seismic bench was used to study various piping elements and is necessary to confirm the performance of mathematical models.
[21]	The paper proposed an assessment of the vibration and seismic resistance of pipelines by the probabilistic modeling method. This method makes it possible to consider random factors associated with spatiotemporal seismic vibrations in various directions, and a probabilistic factor associated with the environment surrounding pipelines. Thus, stochastic uncertainty is accounted for when analyzing the system. However, this approach does not allow assessing the seismic and vibration resistance of individual elements of piping systems and variables not associated with random factors.
[22]	The authors of this article investigated the vibration and seismic resistance of pipeline systems by dynamic modeling using the finite element method. The effects of the friction coefficient in pipe fittings, their diameter and length, were considered. This method will allow assessing vibration and seismic resistance, with regard to the listed parameters. The operability of the method was confirmed, at the same time, these properties of pipelines are necessary, but not sufficient for a full-fledged design of pipeline systems.
[23]	This paper is devoted to the evaluation of the vibration fatigue of a piping system, high pressure and temperatures that lie in different ranges. The forced vibration model of the pipeline system was created on the basis of force analysis and the d'Alembert principle. The correctness of the model was verified in the COMSOL software package. Thus, the effectiveness of evaluating and analyzing fatigue life and strength was proved. The authors emphasize that their research provides a theoretical basis that can be applied to the safe design of the entire system.
[24]	This article studies the seismic resistance of pipelines under uneven longitudinal impact. Tests were carried out on a shake table, as a result of which a three-dimensional finite element mathematical model of the system was constructed. Further, the results obtained by mathematical modeling are compared to experimental ones to identify seismic response of pipeline systems. As a result, it can be concluded that these findings are sufficiently accurate and reliable; thus, this research provides a basis for further experimental studies.

3. SURVEY ITEM

3.1. Description of the Installation Design

Bench Figure 1 is a prefabricated metal structure, consisting of the following units: vibration table (1); power amplifier (2); bench control panel with benchboard (3); and fan (4). The bench also includes diagnostic devices designed to control its vibration impact.

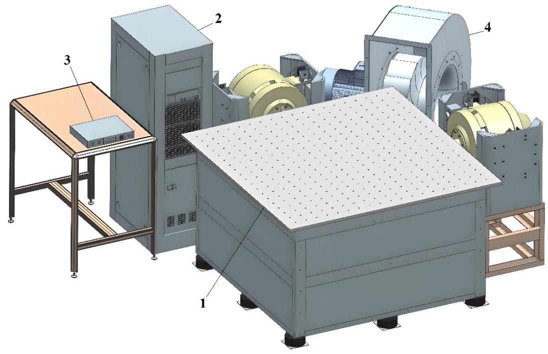

Figure 1. Bench design: 1- vibration table, 2- power amplifier, 3- bench control panel with a benchboard, 4- fan

The power amplifier is intended to control electrical vibration devices that are part of the vibration table. Due to the operation of the amplifier, the excitation signal from an external source is increased and a direct current is generated. The bench control panel with a benchboard provides the generation of the required type of impact and its transmission to the amplifier.

To maintain long and high loads of equipment, an air-cooling system is provided, which maintains stable temperature parameters due to the operation of the fan. The vibration table is intended for stable and continuous generation of vibration impact. The design of the vibration table consists of a base (1), on which the anchor table (2) is installed and vibration motors (3) are attached, providing harmonic loads in the horizontal and vertical planes Figure 2.

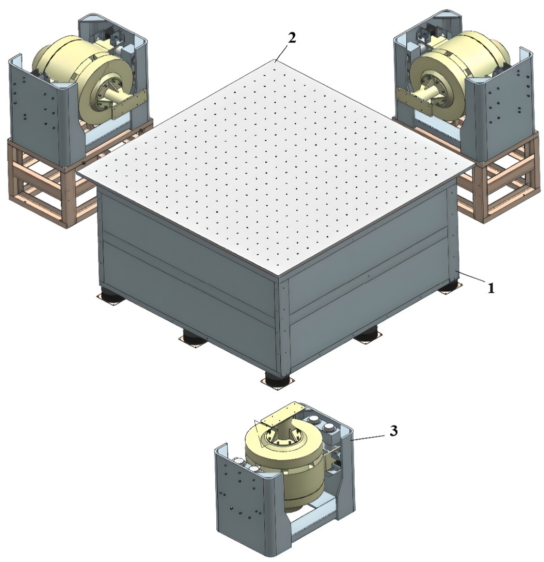

Figure 2. Vibration table design: 1- base, 2- anchor table, 3- vibration motor

The base is a welded metal structure made of standardized profiles, the base frame, to which sheet metal is attached by a screw connection, sheathing, and by welding, the anchor table. The base frame is mounted on vibration mounts using a pin connection, providing free vibrations of the base frame in all directions. Bench vibration motors are made in two versions: horizontal, for generating vibration in the horizontal plane and vertical, for generating vibration in the vertical plane of Figure 3.

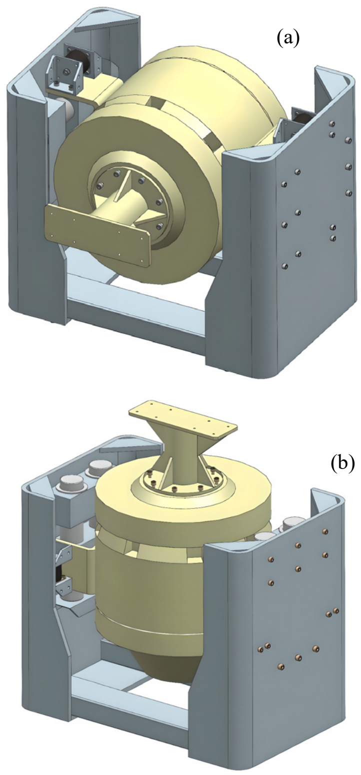

Figure 3. Vibration motor: (a) horizontal, (b) vertical

The vibration motor consists of a trunnion, an electrodynamic vibration motor and a vibration isolation of the trunnion. The vibration motor trunnion is a welded metal structure made of standardized profiles and sheet metal. The vibration motor trunnion is designed for fastening the vibration isolation of the trunnion and the electrodynamic vibration motor. The vibration motor trunnion consists of a base, crossbeams, support sheets and gusset plates.

Trunnion vibration isolation is intended to isolate the trunnion structure from the vibration propagating along it during the operation of the vibration motor. The trunnion vibration isolation consists of two pairs of supports between which a vibration mount is installed. A bracket with a bushing and a stop is required to install the guiding shafts. The carriage serves as a support element for the vibration motor. One of the supports in a pair of trunnion vibration isolation is fixed on the trunnion wall, and the other is connected to the vibration motor mounting frame by a bolted joint. The stop and the bracket are attached to the trunnion wall by a bolted joint.

An electrodynamic vibration motor is the main element in the formation of vibration loads. The principle of operation of an electrodynamic vibration motor is based on creating a directed force in a conductor that is located in a magnetic field and passes an electric current. The conductor is placed on the basis of a cylindrical shape, it constitutes a movable part of the test facility and is fixed within action of the radial magnetic field. A longitudinal force influences the moving part of the structure, the size of which is proportional to the current passing through the conductor. The suspension system helps keep the coil in the area of the magnetic field action with the ability to move the movable part of the structure over a limited distance, which determines the nominal vibration displacement. A flange is attached to the movable end of the electrodynamic vibration motor by a screw joint for connection with the bench base. The horizontal vibration motor is installed on the platform and fixed on it by a bolted joint. The platform is a welded metal structure made of standardized profiles.

3.2. Bench Testing Procedure

Vibration tests play a special role in product quality studies, these tests have been one of the main methods for monitoring the reliability of pipeline assemblies for a long time. Vibration tests provide information on the following factors: material fatigue characteristics, vibration loading and prediction of the durability of tested facilities; assessment of reliability and vibration strength at a given time. In this case, it is impossible to obtain information about the resource of the facilities, because, with the exception of rare cases, tests are conducted in a certain time interval, and not until the destruction of the tested facility.

Thus, vibration tests can be of two types:

1- with a given vibration velocity close to the operational one, in this case, the reliability of the test item is established for a given time interval;

2- with a given voltage, here, the vibration strength is set.

In this case, data are acquired using a capacitive strain sensor because the traditional use of strain sensors is not optimal due to their fragility, and accelerometers do not allow obtaining strain values.

3.3. Research Procedure

The finite element modeling method was used to study the stress-strain state of the bench. The ability to adjust over a wide range makes it possible to adapt the calculation scheme to the geometry of the area under consideration and the boundary conditions, which is an important advantage of this method and can significantly reduce the computation time. Mathematical models are based on the corresponding analytical computations. The three-dimensional problem of the theory of plasticity under active loading is a basis for analytical studies [30]:

$$\begin{cases} \sigma_{ij,j} = 0 \text{ in } V; \\ \sigma_{ij} = F_{ij}(\varepsilon_{kl}) \text{ in } V \cup \sum \\ \varepsilon_{ij} = \dfrac{1}{2}(u_{i,j} + u_{j,i}) \text{ in } V \\ u_i = u_i^{e} \text{ on } \sum_{u_1};\ u_i = 0 \text{ on } \sum_{u_2} \\ \sigma_{ij} n_j = 0 \text{ on } \sum_{\sigma} \end{cases} \tag{1}$$

where, σ_{ij}, ε_{kl} are Cartesian components of stress and strain tensors; u_i is displacement vector components; $F_{ij}(\varepsilon_{kl})$ is nonlinear tensor function describing the plasticity model; $u_{i,j}$ is partial derivatives; u_i^{e} is specified displacements on $\sum_{u1}$ parts of the body surface; $\sum_{u2}$ part of the body surface is assumed rigidly clamped, zero displacements are given on it. For a flat plate, which is a thin parallelepiped with a hole, the edges of which are oriented along the coordinate axes, these displacements were specified on half of the plate hole surface and directed along Ox_1 axis, therefore [30].

$$\begin{aligned} u_1^e &= U(t) = \dot{U}_0\, t \\ u_2^e &= u_3^e = 0 \end{aligned} \tag{2}$$

The seismic bench strength is calculated to determine the most loaded areas and structural elements of the seismic bench under critical loading conditions. To assess the state of the seismic bench structure during research, it is necessary to analyze the stress-strain state of the seismic bench elements using mathematical modeling methods, namely the finite element method (FEM), at maximum static loads in the normal design mode in a finite element software product with automatic division of the structure into finite elements. This simplified analysis is fast and less energy-consuming, it will allow to assess the adequacy of the initial and boundary conditions of the computations, and identify the most loaded areas of the structure that require more attention and detailed analysis.

Based on the initial bench loading data, it is necessary in the strength analysis to determine the maximum displacements and stresses in the parts of all subsystems under their own weight, considering the constant static load on the table of 200 kg. When calculating a seismic bench response to a seismic impact, it is necessary to determine the natural oscillation frequencies, maximum displacements and stresses in the parts of the table subsystem loaded in two directions: vertically (the 1st design case) and horizontally (the 2nd design case). In view of the subsystem symmetry in horizontal directions, it is quite adequate in the 2nd design case to consider the subsystem loading only in one of the two directions.

To increase the efficiency of computations, all fasteners were removed from the assembly, and replaced with surface bonding conditions that work similarly to a fastener. To build a correct finite element mesh, the built-in options for parameterization and setting the size and shape of elements were used (Figure 4).

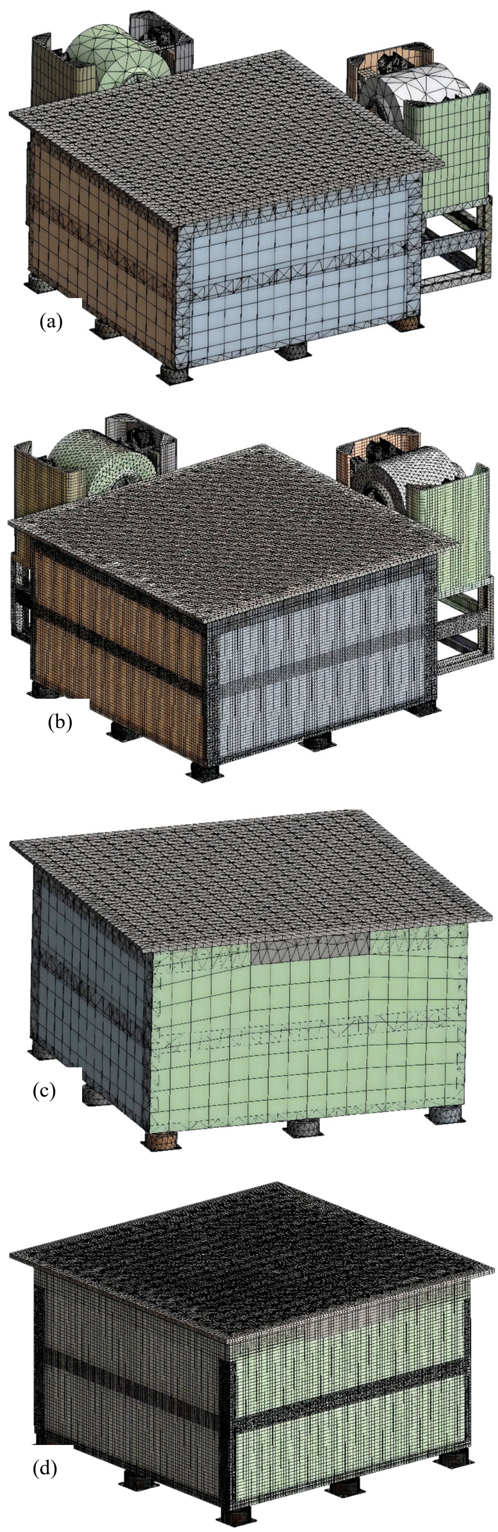

Figure 4. Finite element mesh in the volume of the bench model, created in the automatic mode (a), parameterized regarding the features of the part (b), automatic distribution of finite elements in the volume of the table model for calculating the table response to seismic impact (c) and parameterized with regard to the features of the part (d)

4. MODELING RESULTS

The results of the research are data on the maximum equivalent stresses, maximum deformations and maximum displacements of the installation structural elements, presented in Figures 5-7 and Table 2.

Table 2. Results of the stress-strain state computations

Structure component	Maximum equivalent stresses σ_{max}, MPa	Maximum deformations Δ_{max}, %	Maximum displacements δ_{max}, mm
Motor mounting frames	30	0.04	0.13
Motors	55	2.70	1.64
Motor casing	20	0	0.27
Table frame	30	3.36	3.85
Benchtop	15	0.06	3.85

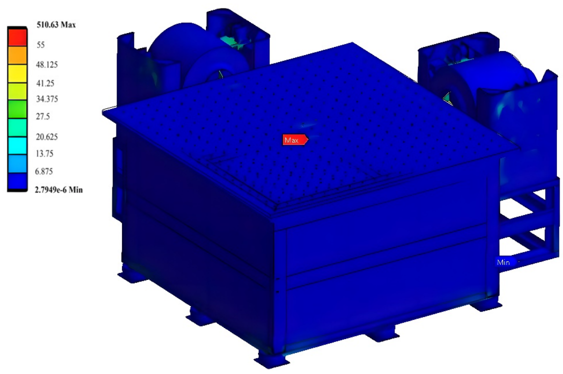

Figure 5. Distribution of equivalent stresses in the volume of the seismic bench model, MPa

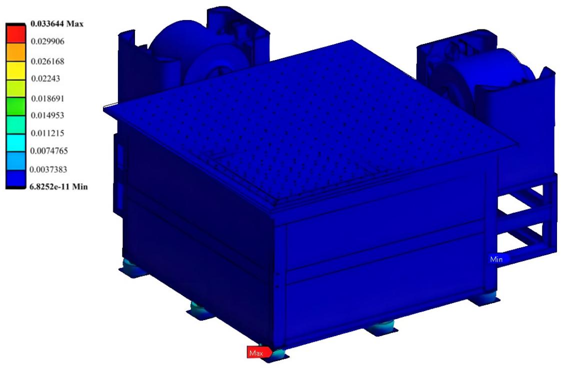

Figure 6. Distribution of equivalent deformations in the volume of the seismic bench model, mm/mm

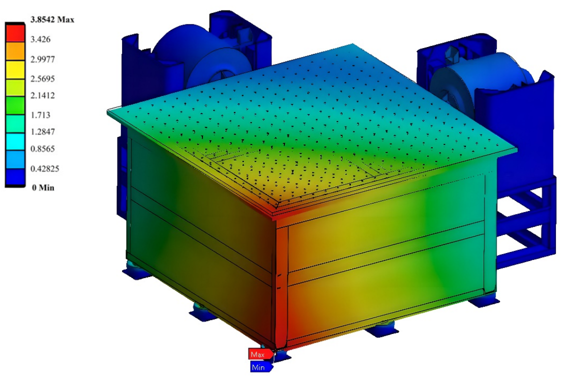

Figure 7. Distribution of maximum displacements in the volume of the seismic bench model, mm

To obtain the system response when conducting a one-factor method (SPRS), it is necessary to combine the contributions of the maximum displacements over the accounted modes of vibration. If these eigenforms occur simultaneously, they are combined in the form of algebraic addition. However, this fact is almost improbable; therefore, the decision will be too conservative. Consequently, shapes should be combined with more realistic methods, such as the root-sum-of-squares method.

In this computation, linear spectral analysis will be used since the load is specified in the form of a response spectrum (dependence of the maximum acceleration values on frequencies). While calculating the table response to seismic impact, its model was simplified by excluding insignificant unloaded and small elements (rounding's, chamfers, etc.) that do not affect the result of the computation. The developed computational model of the table is shown in Figure 8.

Figure 8. The computational model of the table

While calculating the strength of the table model, in accordance with the operating conditions and based on the analysis of the bench design, computational patterns for the multifactorial loading of the table were developed, consisting of two design cases:
1) loads act on the table vertically;
2) loads act on the table horizontally.

Since the table design in the horizontal plane is symmetrical, it is sufficient to carry out the computations along one of the main coordinates (X or Y). Maximum allowable displacement of the table making 51 mm is the determining factor in table performance. In addition, Figures 8-16 and Tables 3 and 4 present the results of calculating the response of the table to seismic impact.

Table 3. Table loading parameters to determine its response to seismic impact

Type of loading	Value
Frequency range, Hz	5-3500
Rated induced force (sinusoidal), kN	1-10
Maximum acceleration, m/s^2	Up to 980

The following assumptions were made during the frequency analysis:
• Chemical composition and aggregate state of materials are unchanged in the process of computation;
• There are no heating processes as a result of deformation;
• There are no extraneous external influences on the base;
• Loads are constant, applied in one direction and do not depend on time.

To conduct a finite element analysis of the table response to seismic impact, structural steel was assigned as a material for the structural components of the table. When calculating the table response to seismic impact, we consider the lower part of the table supports to be immovable, since they are rigidly fixed, and their displacement is limited along the *XYZ* axes of the Cartesian coordinate system. Rotation around all coordinate axes was also limited. Since the largest displacements occur in structures in the first 10 natural frequencies of the considered range, the results of displacements will be presented only for them.

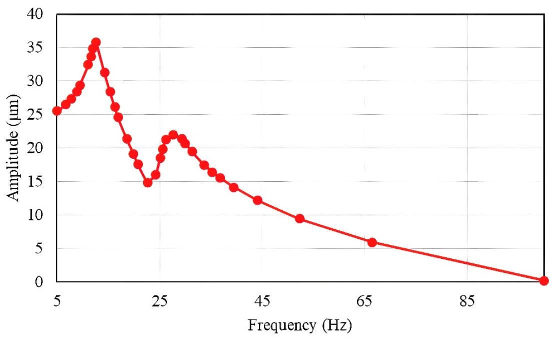

Figure 9. Curve of table vibration amplitude (The 1st design case), mm

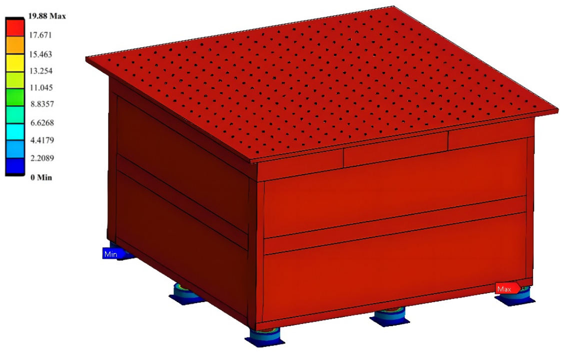

Figure 10. Distribution of maximum displacements in the volume of the table model (The 1st design case), mm

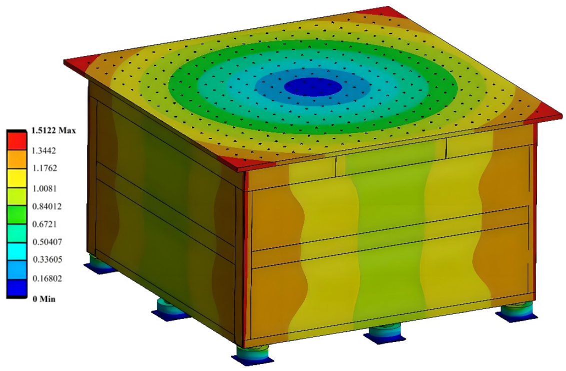

Figure 11. Natural mode shapes of the table, at frequency 1 (The 1st design case), mm

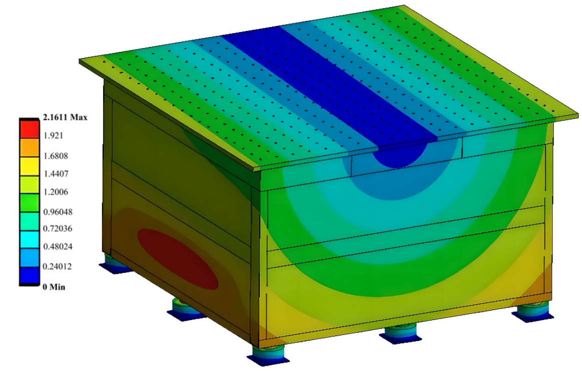

Figure 12. Natural mode shapes of the table, at frequency 3 (The 1st design case), mm

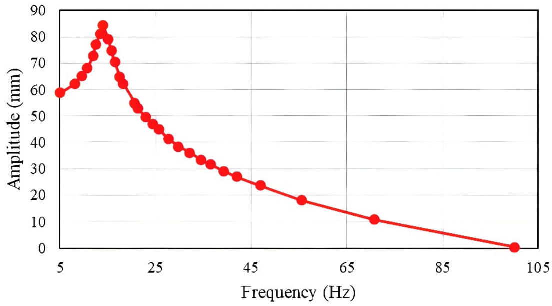

Figure 13. Curve of table vibration amplitude (The 2nd design case), mm

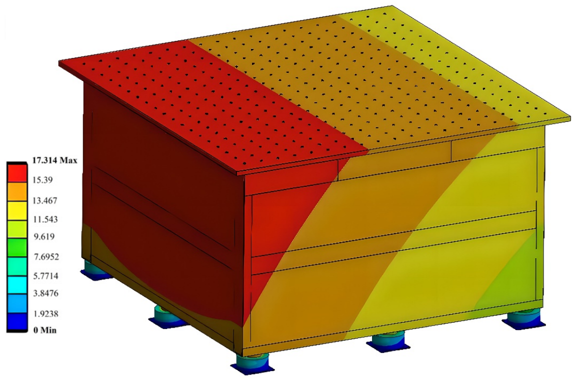

Figure 14. Distribution of maximum displacements in the volume of the table model (The 2nd design case), mm

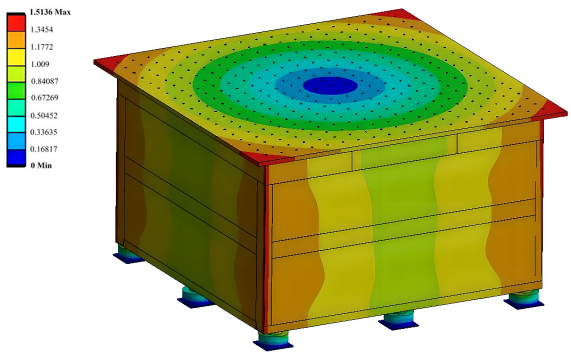

Figure 15. Natural mode shapes of the table, at frequency 1 (The 2nd design case), mm

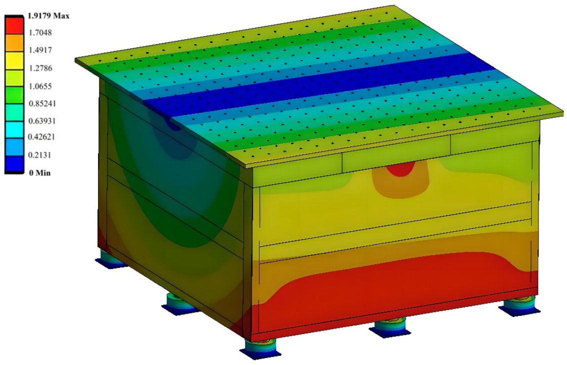

Figure 16. Natural mode shapes of the table, at frequency 3 (The 2nd design case), mm

5. DISCUSSION

As a result of the finite element computation, data were obtained on the maximum stresses, deformations and displacements of the structural components of the plant. The table response to seismic impact was also calculated. The results obtained help evaluate the effectiveness of the developed bench for testing the seismic resistance of pipeline valves much better compared to the existing analogues, because the seismic bench table can move in two planes. Seismic bench has the following limitation - its maximum allowable displacement is 51 mm.

6. CONCLUSIONS

Based on the analysis of the obtained results, conclusion can be made about operating capacity of the proposed design of the bench for testing the seismic resistance of butterfly check valves, intended for in-plant testing of pipeline valves. The design ensures the reproduction of the necessary vibration effect on butterfly check valve prototypes. The conducted studies of the stress-strain state of the bench structure assemblies confirm the achievement of the required level of strength characteristics for ensuring the safe operation of the structure, which makes it possible to proceed to the stage of manufacturing a prototype and practical testing of the bench. This seismic bench will improve the test characteristics of the plant compared to the existing analogues. The limitation in the form of the impossibility of studying large facilities is a disadvantage of such a bench. The improvement of telemetric sensors, i.e., automation of data recording and transmission, is a promising direction for further research.

ACKNOWLEDGEMENTS

Some results of this research were obtained as part of the work under the Subsidy Agreement dated June 24, 2021 No. 075-11-2021-041 on the topic: "Development and Commercialization of the Butterfly Check Valves Model Range for Pipeline Systems of Hazardous Production Facilities with Ultra-High Working Parameters Environment" with the Ministry of Science and Higher Education of Russia.

REFERENCES

[1] B. Fong, M. Housh, G.Y. Hong, J.M. Wang, "Pipeline Management Technologies for Sustainable Water Supply in a Smart City Environment", Reference Module in Earth Systems and Environmental Sciences, Elsevier, 2023 (in press).
[2] T. Rustamli, "Technical Rules for Design and Experimental Research of Fiber Concrete Sewer Pipes", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 54, Vol. 15, No. 1, pp. 87-92, March 2023.
[3] T. Walsh, "The Plastic Piping Industry in North America", Applied Plastics Engineering Handbook, William Andrew Publishing, 2nd Ed., pp. 697-716, 2017.
[4] R.A. Parisher, R.A. Rhea, "Pipe Fittings", Pipe Drafting and Design, Gulf Professional Publishing, 4th Ed., pp. 15-59, 2022.
[5] K. Sotoodeh, "Butterfly Valve Applications and Design", A Practical Guide to Piping and Valves for the Oil and Gas Industry, Gulf Professional Publishing, pp. 147-241, 2021.
[6] Y. Lyu, et al., "Experimental and Molecular Dynamics Simulation Investigations of Adhesion in Heavy Oil/Water/Pipeline Wall Systems During Cold Transportation", Energy, Vol. 250, p. 123811, 2022.
[7] E.B. Liu, et al., "Experiment and Numerical Simulation of Distribution Law of Water-Based Corrosion Inhibitor in Natural Gas Gathering and Transportation Pipeline", Petroleum Science, Vol. 20, No. 3, pp. 1857-1873, 2023.
[8] K. Sotoodeh, "Pipeline Valves", A Practical Guide to Piping and Valves for the Oil and Gas Industry, Gulf Professional Publishing, pp. 505-558, 2021.
[9] B. Hong, et al., "Numerical Simulation of Solid Particle Erosion in the Gas-Liquid Flow of Key Pipe Fittings in Shale Gas Fields", Case Studies in Thermal Engineering, Vol. 42, p. 102742, 2023.
[10] M. Stewart, "Fluid Flow and Pressure Drop", Surface Production Operations, Gulf Professional Publishing, pp. 343-470, 2016.
[11] X. Zheng, et al., "Leak Detection of Long-Distance District Heating Pipeline: A Hydraulic Transient Model-Based Approach", Energy, Vol. 237, p. 121604, 2021.
[12] Q. Liang, C. Peng, X. Li, "A Multi-State Semi-Markov Model for Nuclear Power Plants Piping Systems Subject to Fatigue Damage and Random Shocks Under Dynamic Environments", International Journal of Fatigue, Vol. 168, p. 107448, 2023.
[13] H. Li, et al., "Grouting Sealing Method of Flow-Control Speed-Down in Karst Pipelines and its Engineering Application", Tunnelling and Underground Space Technology, Vol. 108, p. 103695, 2021.
[14] Q.K. Nguyen, et al., "Experimental Study on Pressure Characteristics and Flow Coefficient of Butterfly Valve", International Journal of Naval Architecture and Ocean Engineering, Vol. 15, p. 100495, 2023.
[15] J.N. Aslanov, Kh.S. Mammadov, N.A. Zeynalov, G.A. Hamidova, "Increasing Ball Valve Workability by Changing", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 55, Vol. 15, No. 2, pp. 214-220, June 2023.

[16] A. Olejnik, A. Kapitanov, I. Alexandrov, A. Tatarkanov, "Designing a Tool for Cold Knurling of Fins", Journal of Applied Engineering Science, Vol. 18, No. 3, pp. 305-312, 2020.
[17] M.J. Kaiser, E.W. McAllister, "Control Valves", Pipeline Rules of Thumb Handbook, Gulf Professional Publishing, 9th Ed., pp. 247-284, 2023.
[18] Y. Yan, M. Chai, "Sealing Failure and Fretting Fatigue Behavior of Fittings Induced by Pipeline Vibration", International Journal of Fatigue, Vol. 136, p. 105602, 2020.
[19] X. Wang, P. Zhou, Y. Ma, G. Hu, "Optimization Design on Resonance Avoidance for 3D Piping Systems Based on Wave Approach", International Journal of Pressure Vessels and Piping, Vol. 201, p. 104872, 2023.
[20] A. Ravi Kiran, M.K. Agrawal, "Evaluation of Seismic Margins for Nuclear Power Plant Piping Systems Using Ratcheting Criterion", International Journal of Pressure Vessels and Piping, Vol. 202, p. 104894, 2023.
[21] Y. Wang, A. Xia, G. Qin, "Probabilistic Modeling for Reliability Analysis of Buried Pipelines Subjected to Spatiotemporal Earthquakes", Probabilistic Engineering Mechanics, Vol. 69, p. 103315, 2022.
[22] D. Zhang, et al., "A Dynamic Modeling Approach for Vibration Analysis of Hydraulic Pipeline System with Pipe Fitting", Applied Acoustics, Vol. 197, p. 108952, 2022.
[23] R. Ualiyeva, "Functional Role of Vitelline Glands and Mehlis Gland in the Process of Resistant Egg Shell Formation in Trematodes", OnLine Journal of Biological Sciences, Vol. 23, No. 2, pp. 124-132, 2023.
[24] J. Dai, Z. Wang, Z. Wang, H. Wang, J. Ma, Z. Zhao, "Shake Table Test and Numerical Analysis of the Seismic Response of Buried Long-Distance Pipeline Under Longitudinal Non-Uniform Excitation", Structures, Vol. 47, pp. 1241-1249, 2023.
[25] W. Li, H. Zhang, W. Qu, "Stress Response of a Straight Hydraulic Pipe Under Random Vibration", International Journal of Pressure Vessels and Piping, Vol. 194, p. 104502, 2021.
[26] H. Zhang, M. Qin, K. Liao, K. Wang, G. He, "Pipe-Soil Vibration Characteristics of Natural Gas Pipelines During the Pigging Process", Journal of Natural Gas Science and Engineering, Vol. 95, p. 104148, 2021.
[27] A.A. Tatarkanov, I.A. Alexandrov, M.S. Mikhailov, A.N. Muranov, "Algorithmic Approach to the Assessment Automation of the Pipeline Shut-Off Valves Tightness", International Journal of Engineering Trends and Technology, Vol. 69, No. 12, pp. 147-162, 2021.
[28] I.A. Alexandrov, A.N. Muranov, M.S. Mikhailov, "Development of an Algorithm for Automated Evaluation of the Operability of Structural Elements of Shut-off Valves", International Conference on Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS 2021), pp. 257-261, Yaroslavl, Russia, 06-10 September 2021.
[29] X. Shen, et al., "Reliability Analysis of Bending Fatigue Life of Hydraulic Pipeline", Reliability Engineering and System Safety, Vol. 231, p. 109019, 2023.
[30] J. Lubliner, "Plasticity Theory", Pearson Education, pp. 1-540, London, UK, 2006.

BIOGRAPHIES

Name: **Anastasia**
Middle Name: **Pavlovna**
Surname: **Titova**
Birthday: 10.12.1999
Birth Place: Moscow, Russia
Bachelor: Department of Theoretical and applied mechanics, The Kosygin State University of Russia, Moscow, Russia, 2022
Master: Student, Department of Theoretical and Applied Mechanics, The Kosygin State University of Russia, Moscow, Russia, Since 2022
The Last Scientific Position: Engineer, Center for Technology Transfer, MIREA - Russian Technological University, Moscow, Russia, Since 2022
Research Interests: Mechanical Engineering, Light Industry, Mechatronics

Name: **Abdulmedzhid**
Middle Name: **Magomedovich**
Surname: **Kerimov**
Birthday: 07.06.1960
Birth Place: Makhachkala, Russia
Bachelor: Department of Animal Husbandry, Faculty of Agriculture, Dagestan State Agrarian University, Makhachkala, Russia, 1978
Master: Zoo Engineering, Department of Animal Husbandry, Faculty of Agriculture, Dagestan State Agrarian University, Makhachkala, Russia, 1982
The Last Scientific Position: Researcher, Institute of Design and Technology Informatics, Russian Academy of Sciences, Moscow, Russia, Since 2020
Research Interests: Automation of Technological Preparation of Production, System Analysis, Decision-Making Methods
Scientific Publications: 5 Papers, 3 Theses

Name: **Abas**
Middle Name: **Khasanovich**
Surname: **Lampezhev**
Birthday: 07.07.1997
Birth Place: Murmansk, Russia
Bachelor: Navigation and Ballistic Support for Use of Space Technology, Department of Dynamics and Flight Control of Rockets and Spacecraft, Faculty of Special Mechanical Engineering, Bauman Moscow State Technical University, Moscow, Russia, 2016
Master: Navigation and Ballistic Support for Use of Space Technology, Department of Dynamics and Flight Control of Rockets and Spacecraft, Faculty of Special Mechanical Engineering, Bauman Moscow State Technical University, Moscow, Russia, 2020
The Last Scientific Position: Researcher, Institute of Design and Technology Informatics, Russian Academy of Sciences, Moscow, Russia, Since 2020
Research Interests: Multi-Parameter Optimization and Mathematical Modeling, Multi-Parameter Optimization and Mathematical Modeling
Scientific Publications: 14 Papers, 2 Theses

Name: **Natalia**
Middle Name: **Viktorovna**
Surname: **Dmitrichenko**
Birthday: 19.07.1961
Birth Place: Krasnaya Presnya, Kostanay, Kazakhstan
Bachelor: Teacher of History and Social Studies, Head Teacher-Organizer of Extracurricular Activities, Department of History of Pedagogy, Kostanay Pedagogical Institute, Kostanay, Kazakhstan, Since 1979
Master: Teacher of History and Social Studies, Head Teacher-Organizer of Extracurricular Activities, Department of History of Pedagogy, Kostanay Pedagogical Institute, Kostanay, Kazakhstan, 1985
Research Interests: Manufacture, Industrial Automation, System Analysis, Decision-Making Method
Scientific Publications: 1 Paper