

Abstract of dissertation

on the theme “Research of seismic resistance of a steel vertical cylindrical tank for petroleum products with pre-stressed winding” for the degree of Doctor of Philosophy (PhD) in the study program 8D07320 – “Construction”

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The research objective is a theoretical and experimental assessment of the influence of the design parameters of a pre-stressed winding on the stress-strain state and seismic resistance of a vertical cylindrical tank and, on this basis, the development of an engineering calculation technique and their optimal design.

To achieve this objective, the following **scientific tasks** were solved:

– on the basis of literature data, to study the main design solutions for steel vertical cylindrical tanks for petroleum and petroleum products, to analyze failures and damages to tanks for petroleum and petroleum products as a result of strong earthquakes, to study the features of their dynamic operation in operational conditions, to analyze the regulatory framework to ensure their strength and safety under seismic impacts;

- to conduct a theoretical study of the stress-strain state of the wall of a pre-stressed vertical steel cylindrical tank with constant and variable wall thickness based on the finite element method in the ANSYS software package, taking into account operating conditions and design parameters of the winding;

- to conduct a study of the influence of the parameters of the pre-stressed winding (winding pitch and thickness, winding thread tension force) on the dynamic characteristics of the tank under various operating conditions;

- to conduct experimental studies of models of traditional and pre-stressed tank structures under various pre-stressing parameters and operating conditions and establish the relationship between the design parameters of the winding and the dynamic characteristics of the tank;

- to develop a methodology for engineering calculation and optimal design of vertical cylindrical tanks pre-stressed by a winding for petroleum and petroleum products;

- to substantiate the efficiency of applying the pre-stressing method in vertical cylindrical tanks and describe the manufacturing technology of pre-stressed vertical steel cylindrical tanks for petroleum and petroleum products.

The research object is vertical steel cylindrical tanks for petroleum and petroleum products.

The research subject is seismic resistance of vertical steel cylindrical tanks reinforced with pre-stressed winding.

The research methods: Calculation studies of the stress-strain state and dynamic characteristics of a vertical cylindrical tank were carried out using the ANSYS software package based on the finite element method. The analysis of the

stress-strain state of the model under consideration was carried out in an elastic region that satisfies Hooke's law.

The reliability of the results of experimental studies was ensured by the use of modern proven technical means. Modeling of the tank's geometric dimensions was based on the criteria of mechanical similarity between the model and the full-scale tank, based on the analysis of dimensions.

The reliability of the selected calculation models and the use of the ANSYS software package ensured the validity of the calculation experiment results.

To fix seismic values, a LAW laser linear displacement sensor and a BLOXX-A123 controller were used. The software test.commander and the visualizer test.viewer were used as secondary converters.

The main provisions (proven scientific hypotheses and other conclusions that are new knowledge) submitted for defense:

- values of equivalent stresses in the body of traditional and pre-stressed tank structures with constant and variable wall thickness, taking into account operating conditions and design parameters of the winding, obtained on the basis of the finite element method in the ANSYS software package;

- obtained values of eigenfrequencies and eigenvibrations of a tank without winding and the pre-stressed tank with constant and variable wall thickness, taking into account the influence of pre-stressing parameters and operating conditions;

- the developed algorithm for solving the problem of vibrations of the pre-stressed tank in the ANSYS Workbench using the Modal Acoustics calculation module and the results of studying the vibrations of the steel vertical cylindrical tank with a volume of 3000 m³, reinforced with the pre-stressed winding, taking into account the wall elasticity;

- dependence of the influence of the winding thickness and the winding thread tension on the vertical cylindrical tank's pre-stressed winding frequency and vibration mode;

- the experimental results on the models of the tank without the winding and the tank pre-stressed with the winding to assess the effect of the pre-stressed winding on the dynamic characteristics of the vertical cylindrical tank, taking into account operating conditions;

- the methodology for engineering calculation and optimal design of the pre-stressed tank structures based on the ANSYS software package, which allows to optimally solve the problem of determining the vibration frequencies of the pre-stressed tank reinforced with the winding, taking into account the pre-stressing parameters and the level of liquid filling into the tank.

The research relevance. Today, petroleum and petroleum products are one of the main fuels in the world and the main profitable raw material in the formation of the budget of the Republic of Kazakhstan. Obviously, intensive construction of steel cylindrical tanks will continue, and great attention will be paid to maintaining them in a workable and technically suitable condition, and significant funds will be allocated to restore the bearing capacity of existing steel cylindrical tanks. The construction and operation of vertical cylindrical tanks are associated with high material costs, fire and explosion hazards, the risk of environmental pollution,

danger to human life, and therefore, they are classified as especially critical structures, the design and construction of which should be based on strictly substantiated scientific provisions. and technically possible, fundamentally new design developments, as well as optimal and cost-effective design solutions. The fact that in the Republic of Kazakhstan, areas with increased seismic activity, in which petroleum and petroleum products storage bases are located, under construction or planned to be built, occupy approximately 30% of the territory, makes the problem particularly important.

In this regard, the proposed method for improving the seismic resistance of vertical steel cylindrical tanks reinforced with the pre-stressed winding, is relevant.

Rationale for the need for the research work. The need to develop this topic is associated with emergency situations on vertical cylindrical tanks and their destruction during earthquakes, as well as the need to develop a method for their active seismic protection.

Description of the main research results.

A numerical analysis of the stress-strain state of the steel vertical cylindrical tank of traditional and pre-stressed winding structures under operational loads and various design parameters of the winding was carried out. Equivalent stresses were obtained for the tank with constant and variable wall thickness, which made it possible to evaluate the influence of the winding's design parameters on the tank wall stress state nature at different levels of liquid filling into the tank.

The vibrations of the tank reinforced with the pre-stressed winding were simulated, the methodology was developed for numerical studies of the vibration frequencies and modes of the tank reinforced with the winding in the ANSYS software package, which made it possible to take into account in the calculations the winding thread pitch, thickness and winding force, the influence of roof structures, as well as the level of liquid filling into the tank.

Numerical studies of the “metal structure – liquid” system vibrations were carried out and the vibration frequencies and modes of the tank's pre-stressed winding were determined under various operating conditions and design parameters of the shell, which made it possible to evaluate the effect of the winding's design parameters on the tank wall vibration frequencies and modes' nature, taking into account the operating conditions and install their dependencies.

The experimental research results of the models of the steel vertical cylindrical tank with the pre-stressed winding under various operating conditions and design parameters of the winding for horizontal dynamic effects showed a satisfactory convergence of the frequency values with the values obtained in the calculation experiment. This fact indicates the reliability of the selected calculation models and the vibration frequency values obtained theoretically, and also substantiates the proposed methodology for engineering calculation of the vibration frequencies and modes of the tank pre-stressed with the winding.

Based on the research results, the methodology for engineering calculation and optimal design of the pre-stressed tank structures based on the ANSYS software package was developed, which allows optimally solving the problem of determining the vibration frequencies of the tank pre-stressed with the winding,

taking into account the pre-stressing parameters and the level of liquid filling into the tank.

Compliance with science development directions or government programs. The work was carried out in accordance with the plan of research work of the chair “Construction and construction materials” of M. Auezov South Kazakhstan University on state budget research for 2021-2025. SB RW-21-03-06 “Geotechnical justification for construction of modern construction projects, taking into account factors specific to the south of Kazakhstan”.

The author’s personal contribution. The author substantiated the relevance of the dissertation theme, took part in theoretical and experimental research. He received reliable and substantiated scientific results, on the basis of which he formulated the conclusion and tested the research results.

Approbation of works. The main results of the dissertation work were published in 11 papers: two articles were published in journals from the list of editions recommended by the Committee for Quality Assurance in Higher Education and Science of the Ministry of Higher Education and Science of the Republic of Kazakhstan. Four articles were published in international peer-reviewed journals indexed in the Scopus database (percentile 40) and Web of Science (Q-1). One monograph was published and one patent for an invention was received, issued by the Institute of Intellectual Property of the Republic of Kazakhstan. Three articles were published in an international journal and conferences.

Publications:

1. Tursunkululy T., Zhangabay N., Suleimenov U., Abshenov Kh., Utebayeva A., Moldagaliyev A., Kolesnikov A., Turasheva Zh., Karshyga G., Kozlov P. Analysis of strength and eigenfrequencies of a steel vertical cylindrical tank without liquid, reinforced by a plain composite thread. Case Studies in Construction Materials. – 2023. – 18. – P. e02019. <https://doi.org/10.1016/j.cscm.2023.e02019>

2. Tursunkululy T., Zhangabay N., Avramov, K., Chernobryvko M., Suleimenov U., Utebayeva A., Duissenbekov B., Aikozov Y., Dautbek B., Abdimanat Z. Strength analysis of prestressed vertical cylindrical steel oil tanks under operational and dynamic loads. Eastern-European journal of Enterprise – 2022. – 2. – P. 14-21. <https://doi.org/10.15587/1729-4061.2022.254218>

3. Tursunkululy T., Zhangabay N., Avramov K., Chernobryvko M., Suleimenov U., Utebayeva A. Influence of the parameters of the pre-stressed winding on the oscillations of vertical cylindrical steel oil tanks. Eastern-European journal of Enterprise Technologies. – 2022. – 5/7 (119). – P. 6-13. <https://doi.org/10.15587/1729-4061.2022.265107>

4. Tursunkululy, T., Zhangabay, N., Avramov, K., Chernobryvko, M., Kambarov, M., Abildabekov, A., Narikov, K., & Azatkulov, O. Oscillation frequencies of the reinforced wall of a steel vertical cylindrical tank for petroleum products depending on winding pre-tension. Eastern-European Journal of Enterprise Technologies. – 2023. – 3/7 (123). – P. 14-25. <https://doi.org/10.15587/1729-4061.2023.279098>

5. Tursunkululy T., Zhangabay N.Zh., Buganova S., Daurbekova S. Steel vertical cylindrical tank for petroleum and petroleum products, reinforced with winding. Bulletin of QazBSQA, Almaty. – 2022. – № 4 (86). – P. 210-222. <https://doi.org/10.51488/1680-080X/2022.4-21>

6. Tursunkululy T., Zhangabay N. Analysis of a prestressed steel vertical cylindrical tank taking into account the winding step of steel wire under operating conditions. XI scientific conference, Kharkov, Ukraine, 20 November 2022. – P. 39-40.

7. Ainabekov A.I., Suleimenov U.S., Zhangabay N.Zh., Tursunkululy T. Strength and durability of vertical cylindrical tanks under stress concentration conditions. Monograph. – Shymkent, Publishing house “Alem”. – 2022. – 324 p.

8. Zhangabay N.Zh., Tursunkululy T., Utelbayeva A., Duissenbekov B. Influence of pre-stress on the operating conditions of the tank, taking into account the wire winding pitch. International research journal. – 2022. – № 5 (119). – P. 41-49. <https://doi.org/10.23670/IRJ.2022.119.5.049>

9. Patent for invention № 35915 dated 21.10.2022. Tursunkululy T., Zhangabay N., Zhangabay N.Zh, Suleimenov U., Abshenov Kh., Utelbayeva A. Method for improving the seismic resistance of vertical steel cylindrical tanks using a pre-stressed winding.

10. Zhangabay N.Zh., Utelbayeva A.B., Tursunkululy T., Dautbek B.B. Experimental methodology for pre-stressed shell structures and comparison of experimental results with calculations. VIII scientific conference “Science and education in the modern world”, Nur-Sultan, 2021. – P. 47-55.

11. Zhangabay N.ZH., Utelbayeva A.B., Oner A.K., Tursunkululy T., Khassankhojayeva B.Sh. Ultimate pressure of pre-stressed oil and gas pipelines operating under internal pressure. “Oil and gas” journal, Almaty. – 2020. – № 6 (120). – P. 119-126. http://neft-gas.kz/f/nzh_zhanabaj_ab_utelbaeva.pdf

The structure and scope of the dissertation.

The dissertation work includes the following elements: “Terms and definitions”, “Abbreviations and designations”, “Regulatory references”, “Introduction”, literature review on the problem of seismic stability of tanks and ways to solve it, theoretical part, experimental part and appendix of the research results from 4 sections, “Conclusion”, “References” and “Appendices”.