Annotation of dissertation

subject «Investigation of avalanche destruction and development of ways to prevent them in the main gas pipelines» submitted for the Doctor of Philosophy (PhD) degree under the educational programme 8D07320 – "Civil Engineering"

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The research objective is theoretical and experimental investigation of extended fractures in the main steel gas pipelines and development of a constructive method for localisation and stoppage of the fracture crack by using the prestressing method.

To achieve this objective, the following **research goals** were set and solved:

– A review of the literature regarding accidents and emergencies on the main gas pipelines and factors causing their destruction, as well as a review of works devoted to the research of avalanche destruction. The regulatory framework for safe operation and prevention of avalanche destruction in the main steel gas pipelines was analysed:

- the possibility to apply the winding prestressing method for localisation and stoppage of avalanche destruction in the main gas pipelines was grounded;

- theoretical research of avalanche destruction and stress-strain state of gas main pipelines with traditional design under different operating conditions was carried out based on the finite element method in the software ANSYS.;

- experimental research of traditional and prestressed models for main gas pipeline structures under different prestressing parameters and operating conditions was performed and the possibility and efficiency of fracture crack localisation and stopping in the pipeline by prestressed wrapping was grounded.;

-theoretical research on stoppage and localisation of gas pipelines extended fractures by prestressed winding was done and the effect of pre-stressed winding design parameters on fracture crack localisation in the pipeline was examined.

-methodology of engineering calculation and optimal pre-stressed main gas pipelines design for prevention of their avalanche failures, fracture crack localisation and stoppage was developed.

The research object. Main steel gas pipelines for transporting commercial gas.

The research subject. Avalanche fractures of main steel gas pipelines as a result of fracture crack rapid spread, as well as study of factors causing this destruction.

The research methods. The theoretical research of stress-strain state, character of fracture crack spread in traditional and prestressed pipelines, features of design parameters effect on avalanche fracture process in prestressed winding, as well as study of temperature effect on extended avalanche fracture process in gas main pipelines were performed using ANSYS software based on finite element method. The credibility of the experimental results was assured by the application of modern approved research methods with modern instruments and equipment. The

modelling of geometrical dimensions for gas main pipelines was carried out based on mechanical similarity criteria between a model and a natural tank, which is based on the dimensional analysis.

The credibility of chosen calculation models is substantiated by application of a widely used standard ANSYS software package in technical calculations, as well as by experimental research results of main pipelines models.

Main provisions (proved scientific hypotheses and other conclusions that constitute new knowledge) to be submitted to the defense:

- dependence of traditional and prestressed pipeline avalanche failure criteria on operating conditions and design parameters of prestressing, obtained on the basis of the finite element method with application in software package ANSYS;
- obtained dependences of fracture crack opening (width) and length in the main steel gas pipelines on operating conditions, design solutions and prestressing parameters;
- experimental research results of traditional and prestressed models of the main gas pipeline under different prestressing parameters and operating conditions;
- grounding results of possibility and efficiency for localisation and stoppage the fracture crack in the pipeline by prestressed winding;
- engineering calculation methodology and optimal design of prestressed main gas pipelines to prevent their avalanche failures, localise and stop the fracture cracks.

The relevance of the topic. Nowadays, gas, like oil, is the main source of energy for many consumers in the world. During the last decades, the role and importance of natural gas in the energy balance of world economy is constantly increasing because of its high efficiency as an energy resource and raw material for industry, as well as its higher environmental friendliness in comparison with oil and coal. From 1980 to 2020, the natural gas consumption growth rate was 168 per cent, with oil consumption growth rate of 44 per cent and coal consumption growth rate of 102 per cent in the same period. Natural gas consumption is growing at an average annual rate of 7 per cent. The world's proven natural gas reserves are currently 138 trillion cubic metres. The Republic of Kazakhstan is ranked 14th in terms of proven natural gas reserves with 2.7 trillion m^3. It is evident that intensive construction and reconstruction of steel gas pipelines will continue and great attention will be paid to maintaining them in serviceable and technically suitable condition. It is also evident that considerable funds will be allocated to restore the load-bearing capacity of existing steel main gas pipelines. Since the construction and operation of steel main gas pipelines are associated with high material costs, fire and explosion hazard, risk of environmental pollution and danger to human life, they are considered to be especially responsible structures. Design and construction of such structures should be based on strictly reasonable scientific provisions and technically feasible, fundamentally new design developments, as well as on optimal and economically beneficial design solutions. Particular importance is placed on the issue considering that the gas pipelines in Kazakhstan are more than 70 per cent worn out.

In this connection, the research of avalanche destructions and development of methods to prevent them in the main gas pipelines is actual and well-timed.

Grounds for necessity of the research work. Development of the topic is determined by necessity to develop methods for preventing avalanche destruction in the main steel gas pipelines considering operational conditions, as well as necessity to develop appropriate design and calculation techniques.

Description of the research's main findings.

The theoretical research of avalanche fractures and stress-strain state in the main gas pipelines of traditional design under different operating conditions based on the finite element method in software complex ANSYS was carried out and dependences of fracture crack opening parameters on the pipeline wall from internal pressure and operating temperature were obtained.

The theoretical research of extended fracture process in prestressed winding of gas pipelines was performed and effect of pre-stressed winding design parameters on localisation of fracture crack in the pipeline was studied. Obtained dependences of the fracture crack opening parameters on the design solutions and parameters (spacing, tension and winding angle of thread) of the winding.

Laboratory tests of traditional and prestressed models for main gas pipeline structures under different prestressing parameters and operating conditions were carried out. Experimental results substantiate the possibility and efficiency of localisation and stoppage of fracture crack in the pipeline by prestressed winding. The results obtained as a result of the experiments are new owing to the novelty of the research goal and objectives.

Based on the results of the research, a methodology for engineering calculation and optimal design of prestressed main gas pipelines to prevent their avalanche failures, localise and stop the fracture crack has been developed and proposed, which makes it possible to solve the problem to prevent avalanche failures in the main gas pipelines with regard to prestressing parameters and operating conditions.

Compliance with the science development areas or state programmes. This work was carried out in accordance with a grant financing for scientific and (or) scientific-technical projects in 2023-2025 on the topic: AP19680589 "Development of scientific bases for resistance of main gas pipelines to extended avalanche destruction", financed by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

The author's personal contribution. The author grounded the relevance of the dissertation topic, the research goal and objectives were set, and numerical studies of main gas pipelines were carried out considering the operating conditions and design parameters of prestressing. An experimental research of prestressed main gas pipelines on reduced models modelled on the basis of the classical theory of similarity was carried out. The author obtained credible and grounded scientific results, on the basis of which the conclusion is formulated and the research results are tested.

Approbation of the work. The dissertation work main results are stated in 4 scientific articles, three of which are indexed in Scopus database with percentile index not less than 71 and in Web of Science database with quartile indicator Q1-

Q2. One useful model patent was obtained in the National Institute of Intellectual Property of the Republic of Kazakhstan.

Publications

1. Ibraimova U., Zhangabay N., Tursunkululy T., Rakhimov M., Dossybekov S., Kolesnikov A., Karshyga G., Tengebayev N., Zhirenbayeva N., Liseitsev Y. Development of method for calculation of pre-strained steel cylindrical sheaths in view of the winding angle, pitch and thickness. Case Studies in Construction Materials. Volume 19, December 2023, e02233. https://doi.org/10.1016/j.cscm.2023.e02233
2. Zhangabay N., 1. Ibraimova U., Suleimenov U., Moldagaliyev A., Buganova S., Jumabayev A., Kolesnikov A., Tursunkululy T., Zhiyenkulkyzy D., Khalelova A., Liseitse Y. Factors affecting extended avalanche destructions on long-distance gas pipe lines: Review. Case Studies in Construction Materials. Volume 19, December 2023, e02376. https://doi.org/10.1016/j.cscm.2023.e02376
3. Zhangabay N., Ibraimova U., Bonopera M., Suleimenov U., Avramov K., Chernobryvko M., Utelbayeva A., Uspenskyi B. Finite-Element Modeling of the Dynamic Behavior of a Crack-like Defect in an Internally Pressurized Thin-Walled Steel Cylinder. Applied Sciences 2024, 14(5), 1790. https://doi.org/10.3390/app14051790
4. Zhangabay N., Ibraimova U., Ainabekov A., Buganova S., Moldagaliev A. Finite-Element Modeling of the Temperature Effect on Extended Avalanche destruction of Gas Main Pipelines. Materials 2024, 17(9), 1963. https://doi.org/10.3390/ma17091963
5. Zhangabay N., Ibraimova U., Suleimenov U., Abshenov Kh., Utelbayeva A., Zhangabay A., Duissenbekov B., Moldagaliyev A. Method of localization and stopping avalanche destruction of main gas and oil pipelines. Patent for utility model 12.04.2024., № 9009.

Dissertation structure and scope.

The dissertation work includes the following elements: “Terms and definitions”, “Abbreviations and symbols”, “Regulatory references”, “Introduction”, a literature review devoted to the problem of avalanche destruction in the main gas pipelines, a theoretical part, an experimental part and an appendix of the research results consisting of 4 sections, “Conclusion”, “List of the used sources” and “Appendixes”.