ABSTRACT

to the dissertation for the degree of Doctor of Philosophy (PhD)
in the training area: 8D071 – Engineering,
educational program: 8D07102 – Transport, Transport Equipment and
Technology

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The dissertation topic. Design development and survey on the work of the hoist for loading bulk cargo into containers.

The work relevance. In the state programs for the development of the agro-industrial complex of the Republic of Kazakhstan for 2017-2021, the industrial and innovative development of the Republic of Kazakhstan for 2020-2025, the infrastructure development of the Republic of Kazakhstan "Nurly Zhol" for 2020-2025, the following main problems in the transportation of grain cargo are identified: grain wagons during the season; absence of transportation capacities for the export of grain crops, etc. To solve this problem, representatives of the NC "Kazakhstan Temir Zholy" JSC and the Ministry of Railways of the People's Republic of China decided for the transportation of grain cargoes to be carried out in containers, and the necessary condition for transportation would be calibrating the cargo in bags of 50 kg. However, this is a very time-consuming process, since it is necessary to transship each bag at transshipment points. Therefore, the containerization of grain cargo transportation by rail did not reach the planned volumes.

Today, there are various effective design solutions on this scientific topic for loading bulk cargo into containers for road transport. The preliminary analysis in the Republic of Kazakhstan and abroad showed complete absence of design solutions that allow for efficient loading of bulk cargoes into containers on railway transport. Therefore, issues in the field of transportation by rail of bulk cargo in containers through the development of a hoist for loading require a comprehensive study and development of scientific foundations in this area. In this regard, developing and studying the operation of a hoist for loading bulk cargo into containers is an urgent applied task.

The dissertation work was performed within the framework of the Republican grant of the Science Committee of the Ministry of Education and Science (presently Ministry of Science and Higher Education) of the Republic of Kazakhstan IRN AP14869550 "Design and study of a stationary hoist for loading grain cargo into containers transported by railway platforms".

The purpose of the work is establishing dependences that allow developing a design of a stationary hoist for loading bulk cargo into containers on railway transport.

The main idea of the work is to use a stationary hoist for loading grain cargo through the hoppers of agricultural production elevators, into containers transported by railway platforms.

The tasks of the study. To achieve the purpose, the following tasks were solved:

- a literature and patent review of methods of loading grain cargo in container transportation was carried out;

- a mathematical model of the container filling process was developed and investigated, and dynamic stresses in the design of the load-handling frame of the developed stationary hoist were determined;

- there was experimentally confirmed the hypothesis of the operability of the proposed design of a stationary hoist and processed the experimental data with checking the theoretical data for adequacy;

- a technical specification was developed for the design of a stationary hoist for loading grain cargo into containers transported by railway platforms.

The object of study is a stationary hoist for loading bulk cargo into containers in rail transport.

The subject of study is the stress-strain state of the hoist structure when loading bulk cargo into containers in railway transport.

Research methods. The studies were carried out using a comprehensive research method, including: exploratory research methods (analytical and patent search), strength theories, mathematical research methods and methods for planning and processing experiments.

The scientific novelty is as follows:

- the dependences of stresses in the design of the load-handling frame of a stationary hoist were established for the first time, taking into account the time of loading the container and the radius of the hole in the elevator hopper;

- the relationship between the filling time of the container during the loading of grain cargo was established depending on the radius of the hole in the elevator hopper;

- there was analytically obtained the stress-strain state of the design of the load-handling frame of a stationary hoist dependence on the time of filling the container and the radius of the hole in the elevator hopper;

- the dependences of the stress-strain state of the load-handling frame structure confirming the picture and allowing to determine the main design parameters of a stationary hoist for loading grain cargo into containers transported by railway platforms were experimentally established.

The basic provisions to be defended are as follows:

- the dependence of the container filling time when loading grain cargo should take into account the radius of the hole in the elevator hopper;

- the dependence of stresses in the design of the load-handling frame of a stationary hoist must take into account the dynamic factor that can vary depending on the height of the fall of grain cargo and the radius of the hole in the elevator hopper;

- the stress-strain state of the elements of the load-handling frame of a stationary hoist depends on the movement of the bulk medium (grain cargo), the time of filling the container and the radius of the hole in the elevator hopper.

The validity and reliability of scientific provisions, conclusions and recommendations is confirmed by the use of the main provisions of the theories of strength and mathematical modeling and sufficient convergence of the results of theoretical studies with experimental data.

The practical significance of the work lies in the development of proposals, recommendations and terms of reference for the design of a stationary hoist for loading grain cargo into containers transported by railway platforms.

The author's personal contribution consists in the following:

- setting the goal and tasks of studying and developing a stationary hoist for loading grain cargo into containers transported by railway platforms;

- developing a mathematical model of the container filling process and determining dynamic stresses in the design of the load-handling frame of the developed stationary hoist;

- carrying out experimental studies of the "container – load-handling frame" system in the ANSYS software environment;

- developing the terms of reference for the design of a stationary hoist for loading grain cargo into containers transported by railway platforms.

Implementing the work results. There was received the Act of implementing at the KazTransPromMash LLP of the terms of reference for the development of a stationary hoist for loading bulk cargo into containers on railway platforms, as well as the Act of implementing in the educational process of Abylkas Saginov KTU of the developed methodology of conducting experimental studies of the stress-strain state of the hoist design for loading grain cargo into containers on railway platforms.

Information of publications. The basic provisions of the dissertation were published in 10 scientific papers, including the one with the CiteScore percentile of at least 25 (twenty-five) in the Scopus database, 5 abstracts of reports at international scientific and practical conferences, 4 articles in the editions recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan (now the Ministry of Science and Higher Education of the Republic of Kazakhstan) for publication of the main results of doctoral dissertations. There is conferred a certificate of state registration of rights to the object of copyright and a patent of the Russian Federation for an invention.

The results of the work were reported and discussed in the form of reports at international scientific conferences: at the International Scientific and Practical Conference "Transport of Russia: Problems and Prospects – 2020" (Institute of Transport Problems named after N.S. Solomenko RAS, St. Petersburg, Russia); at the International Scientific and Technical Conference "Sustainable Transport Systems for Sustainable Economy" (Tashkent State Transport University, Tashkent, Uzbekistan); International scientific-practical conference "Actual problems of transport and energy: ways of their innovative solution" (ENU named after L.N. Gumilyov, Astana); at International scientific and practical conferences: Saginov's readings No. 12-2020 and No. 13-2021 (KTU, Karaganda). In the article "Experimental Study of Maximum Stresses in the

Stationary Hoist Design in the Ansys Software Environment" in the journal "Communications - Scientific Letters of the University of Zilina (KOMUNIKACIE)", included in the Scopus database, Mechanical Engineering percentile - 36, https:/ /doi.org/10.26552/com.C.2022.4.B310-B318 the author developed 3D simulation models of the stationary hoist design, conducted an experimental study and obtained positive results. In the article "Experimental study of the strength characteristics of the load-handling frame of a stationary hoist" in the journal "Bulletin of KazATC" (Academy of Logistics and Transport, Almaty, 2022), section "Transport, Transport Engineering", the author investigated the strength characteristics of the load-handling frame of the design of a stationary hoist. In the article "Studying the stress-deformation state of stop fingers for fixing and lifting containers" in the journal "Industrial transport of Kazakhstan" (Kazakh University of Railways, Almaty, 2020), the author studied the stress-strain state of the locking fingers of the stationary hoist structure. In the article "Towards the issue of increasing LPI by improving the method of loading containers" in the journal "University Proceedings" (KTU, Karaganda, 2020), section "Transport", the author developed the design of a stationary hoist and investigated the stress distribution in the container structure when loading bulk cargo.

Conclusion. The dissertation work contains new scientifically substantiated results, the use of which provides solving an important applied problem.

The work volume and structure. The dissertation consists of an introduction, 4 sections and a conclusion, presented on 119 pages of typewritten text, which are explained by 75 drawings, 13 tables, a list of used sources from 104 names and 4 appendices.

Brief conclusions based on the results of dissertation research are as follows.

1. The published literature and patent review of methods of loading grain cargoes during container transportation led to the conclusion that there are no effective constructions of elevators for loading them into containers on railway platforms.

2. Mathematical modeling of static and dynamic stresses in the design of the load-handling frame of a stationary hoist was performed when loading grain cargo into a 20-foot container in the Mathcad software environment. When calculating dynamic stresses, the coefficient of dynamism was taken into account, which could vary depending on the height of the fall of grain cargo and the radius of the opening of the outlet pipes of the elevator loading hopper. In the course of processing and analyzing the results of mathematical modeling, the following results were obtained: dependences of static stresses (σ_i, MPa) on acting loads (F_i/S, MPa) for 4 test positions (at 90°, 60°, 30°, 0°) in the Mathcad software environment; the container filling time dependence on the radius of the opening of the outlet pipes of the loading hopper; the dynamic stresses dependence on the radius of the opening of the outlet pipes of the loading hopper.

3. Experimental studies of the "container – load-handling frame" system were carried out in the ANSYS software environment. The studies were carried out to test the validity of the hypothesis of the proposed design of the load-handling

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frame of a stationary hoist operability for loading grain cargo into containers on railway platforms. In the course of processing and analyzing the results of an experimental study: experimental dependences of output indicators (σ_{ei}, MPa) on influencing factors (F_i/S, MPa) were obtained for 4 test positions (at 90°, 60°, 30°, 0°) in the ANSYS software environment; using the least squares method of the obtained experimental dependences, the empirical equations were determined for 4 test positions (at 90°, 60°, 30°, 0°); comparison of experimental and theoretical indicators revealed positive convergence; the correlation coefficients were determined, showing the degree of closeness of the relationship $r = 98\%$; the coefficients of determination k_d were determined, which made it possible to reveal that 95-98% of the scatter is determined by the x variability, and 1-5% by other reasons, i.e. the variability of functions is almost completely characterized by the spread of the x factors; assessment of the research hypothesis suitability, as well as theoretical data for adequacy (determining the approximation error of experimental data) using the Fisher criterion showed that the models are adequate, i.e. the obtained mathematical models with the confidence probability of 95% describe the process under study well. Comparison of the calculation results performed in the Mathcad application program with the results of test tests performed in the ANSYS software environment, in general, confirmed the adequacy of the calculated values, and the error does not exceed 30%.

4. There were determined the main parameters and recommended the equipment for the developed stationary hoist: a principal hydraulic diagram of the translational movement of the hydraulic drives for lifting and lowering the load-handling frame is proposed; calculations and selection of hydraulic cylinders, pumps, electric motors, materials for the load-handling frame; the modes of operation of the hoist are considered, which made it possible to determine the stroke of the rods of hydraulic cylinders during the operation of these modes.

5. "The terms of reference for the development of a stationary hoist for loading bulk cargo into containers on railway platforms" was developed.

Development of recommendations and baseline data for the specific use of the results. The developed method of calculating the container filling process and dynamic stresses in the design of the load-handling frame of the stationary hoist being developed can be recommended to scientific, engineering and technical workers involved in the design of handling equipment, as well as to design and research institutes. The initial data for the specific use of the results are the results of the performed research and experimental work.

Evaluation of the technical and economic efficiency of implementation. The annual economic effect from introducing of the developed stationary hoist in the conditions of the Sarybel elevator is within 25 million tenge.

Evaluation of the scientific level of the work performed in comparison with the best achievements in this field. In this work, the following results were firstly obtained:

- the dependences of stresses in the design of the load-handling frame of a stationary hoist were established for the first time, taking into account the time of loading the container and the radius of the hole in the elevator hopper;

- the relationship between the filling time of the container during the loading of grain cargo was established, depending on the radius of the hole in the elevator hopper;

- there was analytically obtained the stress-strain state of the design of the load-handling frame of a stationary hoist dependence on the time of filling the container and the radius of the hole in the elevator hopper;

- there were experimentally established the stress-strain state of the load-handling frame structure dependences that confirm the picture and allow determining the main design parameters of a stationary hoist for loading grain cargo into containers transported by railway platforms.