EXPERIMENTAL STUDY OF MAXIMUM STRESSES IN THE STATIONARY HOIST DESIGN IN THE ANSYS SOFTWARE ENVIRONMENT

Aidana Donenbaykyzy Kassymzhanova 1, Marat Kenesovich Ibatov 1, Oyum Temirgalievich Balabayev 1, Bakytzhan Serikovich Donenbaev 1, Daurenbek Ikhtiyarovich Ilessaliyev 2

1 Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan
2 Tashkent State Transport University, Tashkent, Uzbekistan

E-mail of corresponding author: balabaev.ot@mail.ru

Resume

The authors have studied the methods of loading bulk cargo in the railway transport. The developed method of loading bulk cargoes into containers transported by railway platforms has been developed. The article deals with experimental studies of maximum stresses in the design of the proposed stationary hoist. The studies have been carried out in the ANSYS software environment with development of simulation models of the hoist design.

1 Introduction

The growth of container traffic is a global trend; this is also typical for the countries of Central Asia (Kazakhstan, Afghanistan, Tajikistan, Uzbekistan). A special role is played by the general advantages of containers: their convenience and economy in the freight transportation. Economic and geographical factors, development of the Central Asia countries’ economies, as well as development of the Chinese economy resulted in the railway freight traffic with Europe becoming very important. Thus, development of a method to improve the efficiency of loading operations for containers transported by railway platforms is an urgent task.

In 2010, at the meeting, representatives of the NC “Kazakhstan Temir Zholy” JSC (Kazakhstan Railways) and the Ministry of Railways of China decided that wheat would be transported in containers and a necessary condition for transportation would be tare the cargo in 50 kg bags [1]. However, this is a very time-consuming process, since it is necessary to transship each bag at transshipment points. Despite the fact that bulk cargo requires bulk transportation, the decision to transport bagged wheat is due to the lack of the necessary infrastructure to ensure the loading and unloading of bulk cargo into containers.

The COVID-19 pandemic has shown that China began demanding to deliver grain in containers loaded in big bags, where the human presence during loading and unloading operations is minimized and forklifts came to the rescue. The practice has shown that containers arriving at the station are promptly accepted, unloaded, overloaded by the Chinese side, so, there are fewer delays. Since the issue of loading wheat into rail containers in bulk has not been fully resolved, one can confidently say that the potential of container transportation in rail transport is not fully used.

Considering the difference in railway gauge, when transporting goods through the new Asia-European Continental Bridge, it is necessary to transship cargo twice during the transportation to Europe. As a result, duration of the goods’ transportation increases accordingly, at the transshipment point of the border port, goods are likely to be delayed. A certain difference in gauge exists in Asian and European countries. One of the solutions will be containerization and development of the intermodal transportation.

It is obvious that the increase in intermodal
of which is mentioned in the paper of colleagues, where the process associated with the operation conducted on intermodal transport units, for example a large type A container, including inter alia: simple operations and combinations of operations (so-called combined cycles) were presented [6]. However, this transport and technological system, where a tractor-trailer is used, cannot be implemented when loading the bulk cargo into containers on railway tracks, in the cramped conditions of agricultural elevators.

The solution of this problem would contribute to the growth dynamics of the export potential of bulk cargoes, by improving the transport infrastructure.

The growth dynamics of container traffic shows that, if needed, it is possible to organize the loading of returnable containers from the bulk cargo with other types of imported cargo in order to exclude empty containers from entering the country or to organize multimodal transportation along other routes, Figure 1.

As a result of reviewing and analyzing design solutions of loading and unloading bulk cargoes [4-5], it can be said that the developed devices only perform loading into road or rail vehicles and there are currently no devices for loading bulk cargoes into containers for their transportation by railway platforms. A good solution to the problem could be the use of tractor-trailers, the so-called reach stackers, by the way, the work of which is mentioned in the paper of colleagues, where the process associated with the operation conducted on intermodal transport units, for example a large type A container, including inter alia: simple operations and combinations of operations (so-called combined cycles) were presented [6]. However, this transport and technological system, where a tractor-trailer is used, cannot be implemented when loading the bulk cargo into containers on railway tracks, in the cramped conditions of agricultural elevators.

The solution of this problem would contribute to the growth dynamics of the export potential of bulk cargoes, by improving the transport infrastructure.

To solve this problem, at Abylkas Saginov Karaganda Technical University, the authors of this article have developed the design of a stationary hoist (Figure 2) for loading containers transported by railway platforms [7].

The technical result of the invention is to increase the efficiency of loading the bulk cargo into containers transported by railway platforms. The specified technical

Figure 1 Cargo traffic in containers using all types of transport

Figure 2 The structure diagram of the developed stationary hoist with indication of the main nodes:
1 - hydraulic lift, 2 - railway track, 3 - load-handling frames, 4 - horizontal drives, 5 - locks, 6 - vertical drives, 7 - supporting frames, 8 - lifting drives, 9 - devices for opening and closing the hatches of the container
result is achieved by the fact that the following changes have been made to the considered method of loading containers transported by railway platforms: a lift is mounted on the railway track; it is equipped with devices for rotating and mounting a container with the end wall on the railway platform for loading bulk cargo [7].

The research methodology is provided by:
- planning the procedure for carrying out experimental studies;
- establishing the influencing factors and output indicators;
- selecting the number of test trials and test positions;
- performing experimental studies with calculations and design of simulation models in the ANSYS software environment;
- comparison of the experimental studies’ results to results of theoretical studies performed in the Mathcad software environment.

To determine the rational design parameters, the article presents a detailed study of the proposed lift design with development of a simulation model in the ANSYS software environment.

2 Purpose and plan of experimental studies

The purpose of experimental studies was to confirm the operability of the proposed design of a stationary hoist (Figure 2) for loading the grain cargo into containers on railway platforms.

To achieve this purpose, it is necessary to solve the following tasks [8]:
- to plan the procedure for carrying out experimental studies of the “container-hoist” system;
- to establish the influencing factors and output indicators;
- to select the number of test trials and test positions [8-9];
- to perform experimental studies with calculations and development of simulation models in the ANSYS software environment;
- to compare the results of experimental studies to results of theoretical studies performed in the Mathcad software environment.

Experimental studies of the “container-hoist” system include the following stages:

1. Establishing the influencing factors and output indicators. The influencing factor is the force that is loaded on a certain area of the structure of the developed stationary hoist ($F_i/S$, MPa). The output indicator, as the most important characteristics of the process under study, considered in the design of a stationary hoist after the application of a force, is selected: mechanical stresses ($\sigma_{Ei}$, MPa) that occur in the design of a stationary hoist.

2. Selecting the number of test trials and test positions. The object of experimental studies is
3 Experimental studies

Simulation computations represent a very effective tool for investigating operational characteristics and behaviours of constructions without having a real product [12]. Simulation modeling of the design of a stationary hoist in the ANSYS software environment has begun with development of sketches by size and then, using the ANSYS tools, the simulation models of the developed stationary hoist in 4 test positions were obtained (Figure 4).

After developing the simulation models for the design of the developed stationary hoist in the ANSYS software environment, when carrying out experimental studies:

- the properties of construction materials have been set;
- the forces and directions of forces acting on the structure have been given;
- the process of calculation by the finite element method has been performed, taking into account all the specified parameters.

3. Carrying out experimental studies in the ANSYS software environment.

When performing the experimental studies in the ANSYS software environment, it is necessary to:

- perform the simulation modeling of the stationary hoist design;
- carry out 32 test trials of the stationary hoist design for 4 test positions with 8 loadings;
- receive reports of test results.
Table 1 Maximum stresses in the structure according to 32 test trials for 4 tested positions

| Test trials | No.1 | No.2 | No.3 | No.4 | No.5 | No.6 | No.7 | No.8 |
|-------------|------|------|------|------|------|------|------|------|
| Loadings to the structure, $m / F_i / S$, ton / MPa | 25 / | 35 / | 45 / | 55 / | 65 / | 75 / | 85 / | 95 / |
| I | 25.043 | 37.484 | 48.491 | 65.679 | 80.003 | 92.078 | 106.650 | 121.230 |
| II | 14.237 | 20.221 | 22.443 | 27.665 | 30.144 | 32.418 | 34.448 | 36.351 |
| III | 54.022 | 70.103 | 87.192 | 103.230 | 120.700 | 137.200 | 154.200 | 170.690 |
| IV | 75.393 | 102.990 | 130.340 | 157.480 | 183.430 | 209.490 | 239.480 | 267.470 |

Figure 5 Results of the first test trial for a position I - 90° (see Table 1)

Figure 6 Results of the first test trial for position II - 60°

Figure 7 Results of the first test trial for position III - 30°
4 Results of experimental studies

When carrying out experimental studies of the “container-hoist” system, 32 test runs have been performed (Table 1) for 4 test positions (Figures 2 and 3): I - at 90 degrees; II - at 60 degrees; III - at 30 degrees; IV - at 0 degrees. The 8 planned loadings have been performed: 25 t; 35 t; 45 t; 55 t; 65 t; 75 t; 85 t; 95 t. At the end of each test run, the ANSYS application program produced the stress diagrams in the load-handling frame.
coordinates and connected by experimental points into experimental dependences

\[ \sigma_{Ei} = f\left(F_i/S, \text{MPa}\right) \]. Figures 9 to 12 show experimental dependences for 32 test runs (Table 2) for 4 test positions. The graphs show that the mechanical stresses (\(\sigma_{Ei}, \text{MPa}\)), which arise in the design structure with the results of calculating the output indicators (Figures 5 to 8).

After carrying out experimental studies of the “container-hoist” system, the results of 32 test trials for 4 test positions have been plotted on a grid of rectangular coordinates and connected by experimental points into experimental dependences \(\sigma_{Ei} = f(F_i/S)\). Figures 9 to 12 show experimental dependences for 32 test runs (Table 2) for 4 test positions. The graphs show that the mechanical stresses (\(\sigma_{Ei}, \text{MPa}\)), which arise in the design structure with the results of calculating the output indicators (Figures 5 to 8).

### Table 2 Convergence of experimental (Ansys) and theoretical indicators (Mathcad)

| Test No. | Experimental and theoretical indicators |
|----------|----------------------------------------|
|          | I - at 90 degrees | II - at 60 degrees | III - at 30 degrees | IV - at 0 degrees |
|          | yei | ythi | % | yei | ythi | % | yei | ythi | % | yei | ythi | % |
| 1        | 25.043 | 28.335 | 0.12 | 14.237 | 11.267 | -0.26 | 54.022 | 42.873 | -0.26 | 75.393 | 62.990 | -0.20 |
| 2        | 37.484 | 39.669 | 0.06 | 20.221 | 15.774 | -0.28 | 70.103 | 60.022 | -0.17 | 102.990 | 88.186 | -0.17 |
| 3        | 48.491 | 51.003 | 0.05 | 22.443 | 20.281 | -0.11 | 87.192 | 77.171 | -0.13 | 130.340 | 113.382 | -0.15 |
| 4        | 65.679 | 62.337 | -0.05 | 27.665 | 24.788 | -0.12 | 103.230 | 94.320 | -0.09 | 157.480 | 138.578 | -0.14 |
| 5        | 80.003 | 73.671 | -0.09 | 30.144 | 29.295 | -0.03 | 120.700 | 111.469 | -0.08 | 183.430 | 163.775 | -0.12 |
| 6        | 92.078 | 85.005 | -0.08 | 32.418 | 33.802 | 0.04 | 137.200 | 128.618 | -0.07 | 209.490 | 188.971 | -0.11 |
| 7        | 106.650 | 96.339 | -0.11 | 34.448 | 38.308 | 0.10 | 154.200 | 145.767 | -0.06 | 239.480 | 214.167 | -0.12 |
| 8        | 121.230 | 107.673 | -0.13 | 36.351 | 42.815 | 0.15 | 170.690 | 162.916 | -0.05 | 267.470 | 239.363 | -0.12 |
of a stationary hoist increase as the load increases.

A comparison of the theoretical calculations results, performed in the Mathcad application program (Table 2), to results of experimental studies (Table 1), performed in the ANSYS software environment, has in general confirmed the adequacy of the calculated values and the error does not exceed 30%.

5 Conclusions

To increase the export potential of the bulk cargoes of the Republic of Kazakhstan, the authors of this article have proposed a stationary hoist design for loading the bulk cargo into containers transported by railway platforms. The proposed method was patented in the Derwent patent database, Clarivate Analytics [7].

To determine the rational design parameters, the stationary hoist operation has been simulated in the ANSYS software environment. Total of 32 test trials for 4 test positions of experimental studies were carried out. They have proved that the stationary hoist design is able to withstand emerging mechanical stresses ($\sigma_{Ei}$, MPa) up to 833.85 MPa, or 85 t, while the yield strength of the selected construction material (Structural Steel) is 250 MPa. The convergence of the experimental indicators, presented in the article with the theoretical data obtained in the Mathcad application program, has confirmed the adequacy of the calculated values and the error does not exceed 30%.

Acknowledgement

This research has was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP14869550, “Design and study of a stationary hoist for loading grain cargo into containers transported by railway platforms”).

References

[1] CHERNOMOROV, A. G. Creation of a transshipment system at Dostyk station for the purpose of transporting grain cargoes in international traffic. The Bulletin of Kazakh Academy of Transport and Communications named after M. Tynyshpayev. 2011, 3, p. 44-46. ISSN 1609-1817.

[2] ZAJAC, M., SWIEBODA, J. Analysis of the process of unloading containers at the inland container terminal. In: Safety and reliability: methodology and applications. NOWAKOWSKI, T., MLYNZAK, M., JODEJKO-PIETRUCZUK, A., WERBINSKA-WOJCIECHOWSKA, S. (eds.). London, UK: Taylor and Francis Group, 2014. eISBN 9780429226823, p. 1237-1241.

[3] Official website of the Agency for Strategic planning and reforms of the Republic of Kazakhstan Bureau of National Statistics. Transportation of goods in containers by all modes of transport. [online] [accessed 2022-07-07]. Available from: https://www.stat.gov.kz/search/transportation of goods in containers by all modes of transport

[4] Patent RU 2 127 703 C1 Method of loading and unloading containers transported by railway platforms. 1999.

[5] Patent WO/2005/030822 A method and system for filling the entire volume of 20 feet steel shipping containers. 2005.

[6] KOSTRZEWSKI, M., KOSTRZEWSKI, A. Analysis of operations upon entry into intermodal freight terminals. Applied Sciences [online]. 2019, 9(12), 2558. eISSN 2076-3417. Available from: https://doi.org/10.3390/app9122558

[7] VITVITSKIY, E. E., GUMAROV, G. S., BALABAEEV, O. T., ABISHEV, K. K., SARZHANOVOV, D. K., KASSYMZHANOVA, A. D. Method of loading bulk goods in containers transported by railway. Patent number(s): RU2654439-C1 for invention. Derwent primary accession number: 2018-53628L. Database: Derwent innovations index of Web of Science maintained by Clarivate Analytics.

[8] KASSYMZHANOVA, A. D. Certificate of the Republic of Kazakhstan on including the information into the State register of rights to objects protected by copyright. Methods of carrying out experimental studies of the stress-strain state of the design of a stationary hoist designed for loading grain cargo into containers on railway platforms. No. 26526. 2022.

[9] KADYROV, A., KARSAKOVA, A., DONENBAEV, B., BALABEKOVA, K. Establishing the strength characteristics of the lifting-leveling device structures of the VPO-3-3000 machines for the track straightening. Communications - Scientific Letters of the University of Zilina [online]. 2020, 22(4), p. 70-79. ISSN 1335-4205, eISSN 2585-7878. Available from: https://doi.org/10.26552/com.C.2020.4.70-79

[10] KASSYMZHANOVA, A. D. Certificate of the Republic of Kazakhstan on including the information into the state register of rights to objects protected by copyright. Methods of carrying out experimental studies of the stress-strain state of the design of a stationary hoist designed for loading grain cargo into containers on railway platforms [online]. No. 26526. 2022. Available from: https://copyright.kazpatent.kz/?!iD=wQEy

[11] PROTODYAKONOV, M. M., TEDER, R. I. Methods of rational planning of experiments. Moscow: Science, 1970.
[12] DIZO, J., BLATNICKY, M., HARUSINEC, J., SUCHANEK, A. Assessment of dynamics of a rail vehicle in terms of running properties while moving on a real track model. *Symmetry* [online]. 2022, 14(3), 536. eISSN 2073-8994. Available from: https://doi.org/10.3390/sym14030536