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

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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.

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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 50kg 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

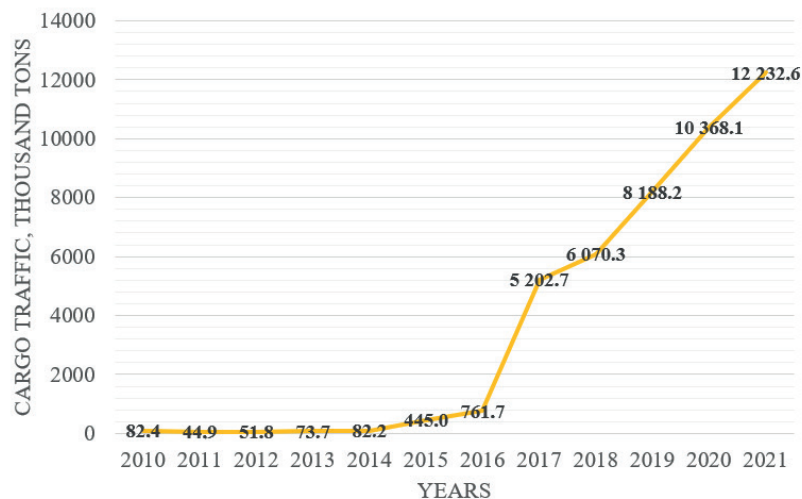


Figure 1 Cargo traffic in containers using all types of transport

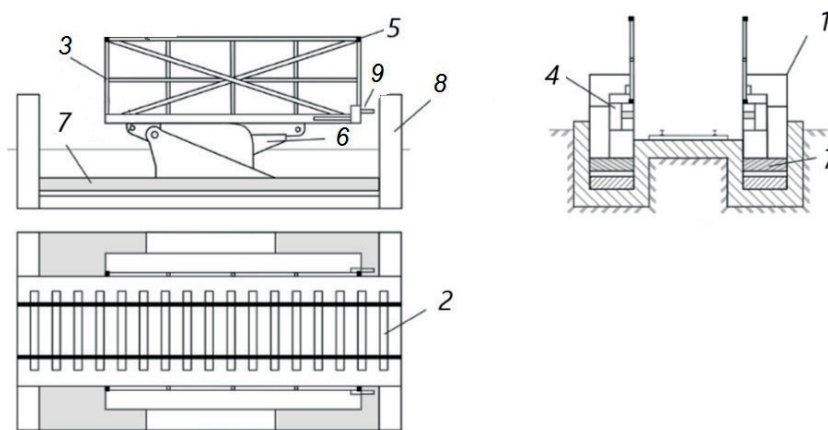


Figure 2 The structure diagram of the developed stationary hoist with indication of the main nodes:

- 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

transport is a natural phenomenon [2]. When analyzing the freight transportation in containers, in the Republic of Kazakhstan over the past years, a sharp increase in container traffic was observed since 2017, while since 2018 this figure has been growing with an arithmetic progression (Figure 1) [3].

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

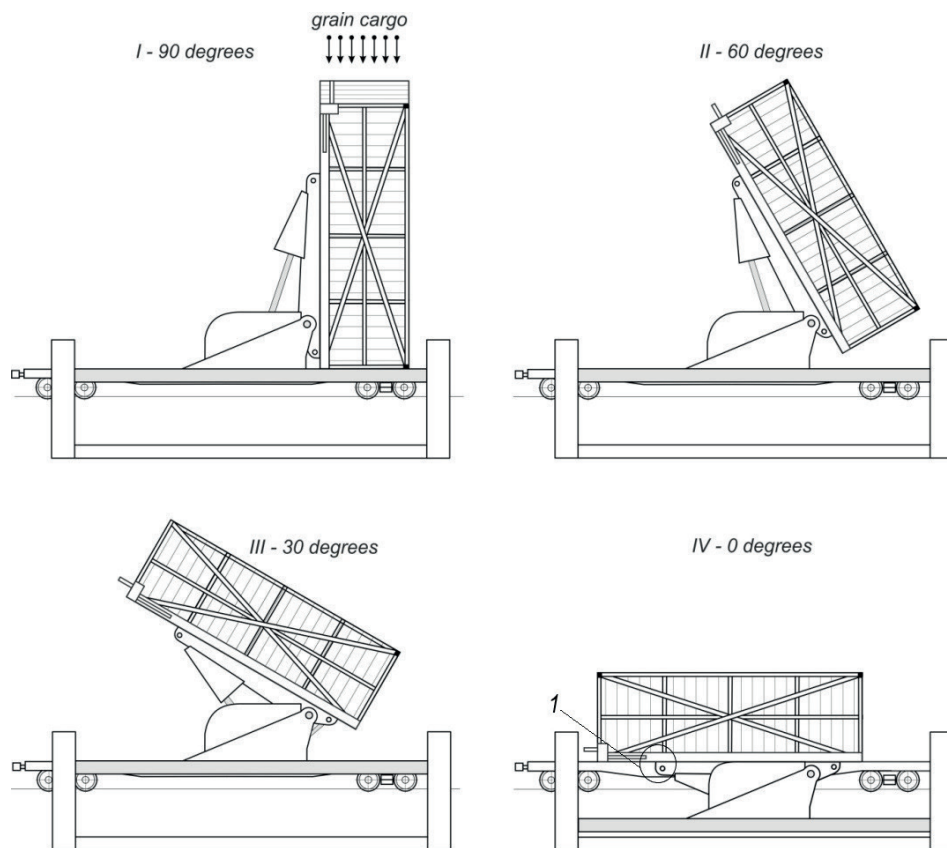


Figure 3 Test positions of the stationary hoist
(1 - section with maximum stress, figures 5 to 8)

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 (σ_{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

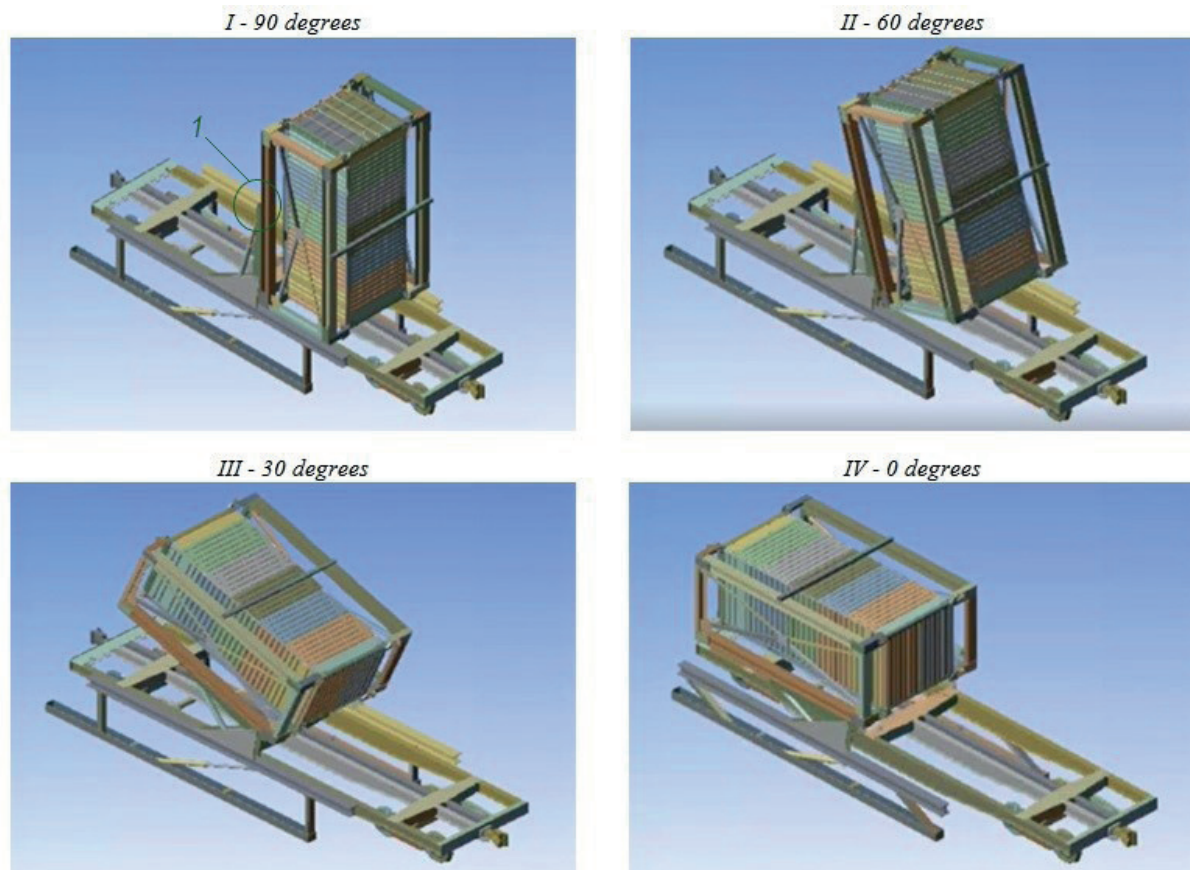


Figure 4 Simulation 3D modeling of the developed stationary hoist in the ANSYS software environment (1 - section with maximum stress, figures 5-8)

the “container-hoist” system, implemented in the form of simulation models in the ANSYS software environment [10], which have been designed to solve the goal of the experiment. This system can be represented as a “black box” of a single-factor experiment, where the input influencing factor is the stress (F_i/S , MPa) and the output parameter (response function) is mechanical stress (σ_{Ei} , MPa). Thus, the registration of the output parameter in a single-factor experiment is carried out with considering the influence of one factor and determining one value of the output parameter. Based on the above conditions and according to the Methodology of rational planning of experiments [11], for obtaining the results, it is necessary to perform $N=I^l=1$ experiments for each planned loading: 25 t; 35 t; 45 t; 55 t; 65 t; 75 t; 85 t; 95 t. Thus, for experimental studies, it is accepted to carry out 8 loadings for the selected positions of the developed stationary hoist (Figure 3), i.e. 32 test trials for 4 test positions environment [10].

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.

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.

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 / 245.250	35 / 343.350	45 / 441.450	55 / 539.550	65 / 637.650	75 / 735.750	85 / 833.850	95 / 931.950
Stresses in the test positions, σ_{E^2} MPa	I	25.043	37.484	48.491	65.679	80.003	92.078	106.650
	II	14.237	20.221	22.443	27.665	30.144	32.418	34.448
	III	54.022	70.103	87.192	103.230	120.700	137.200	154.200
	IV	75.393	102.990	130.340	157.480	183.430	209.490	239.480

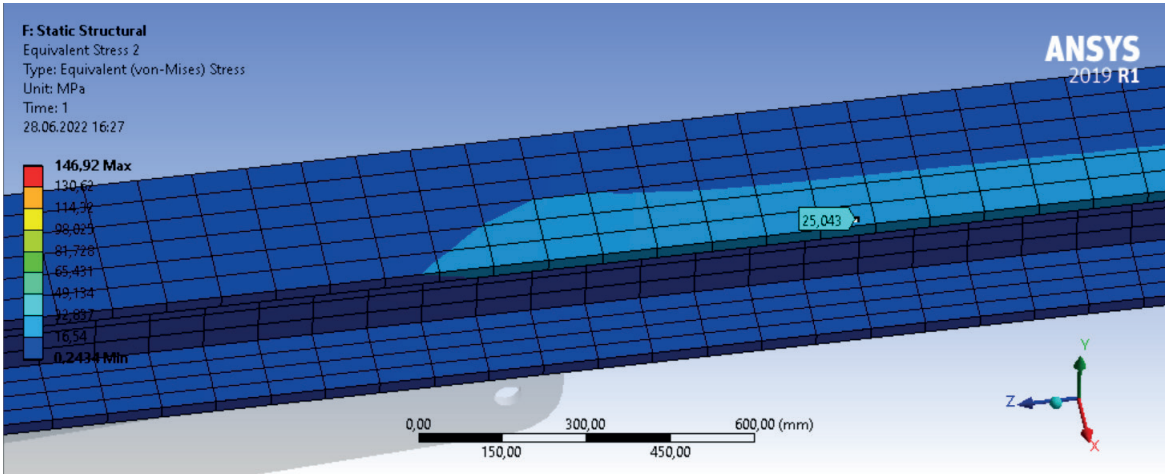


Figure 5 Results of the first test trial for a position I - 90° (see Table 1)

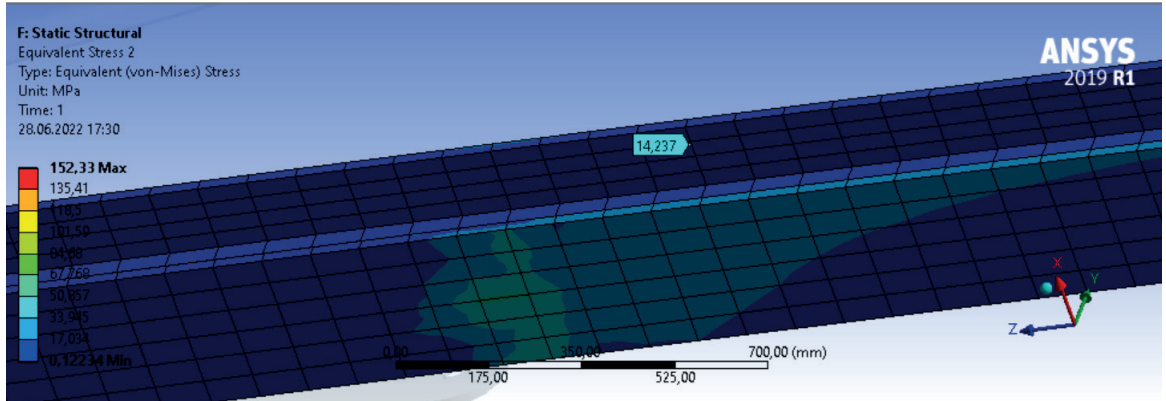


Figure 6 Results of the first test trial for position II - 60°

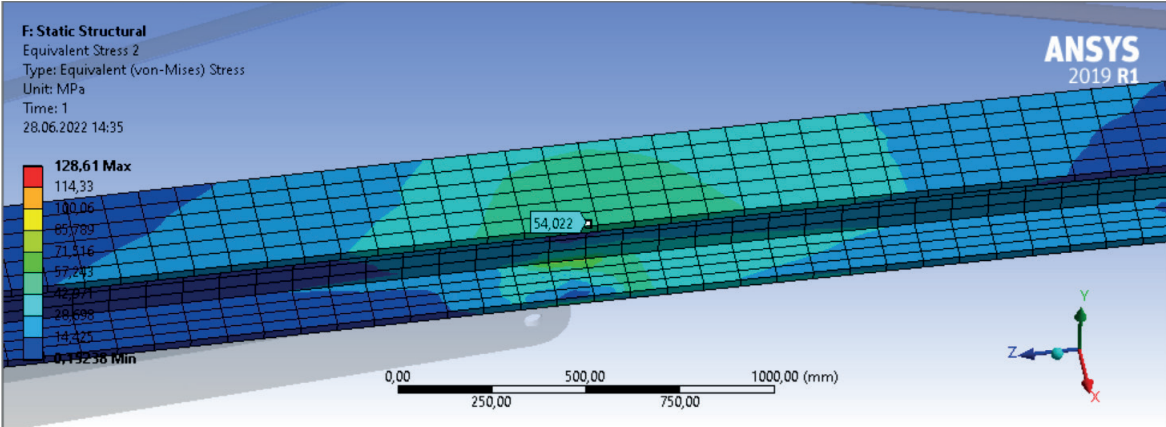


Figure 7 Results of the first test trial for position III - 30°

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

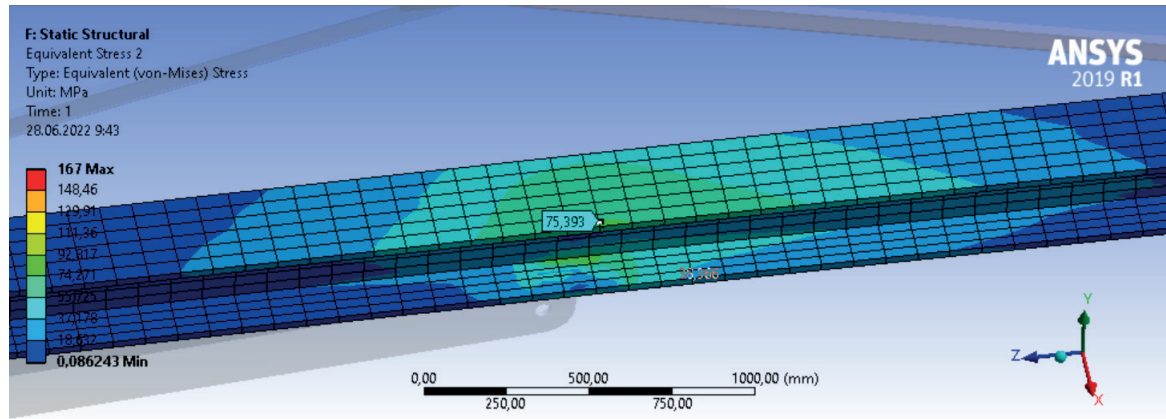


Figure 8 Results of the first test trial for position IV - 0°

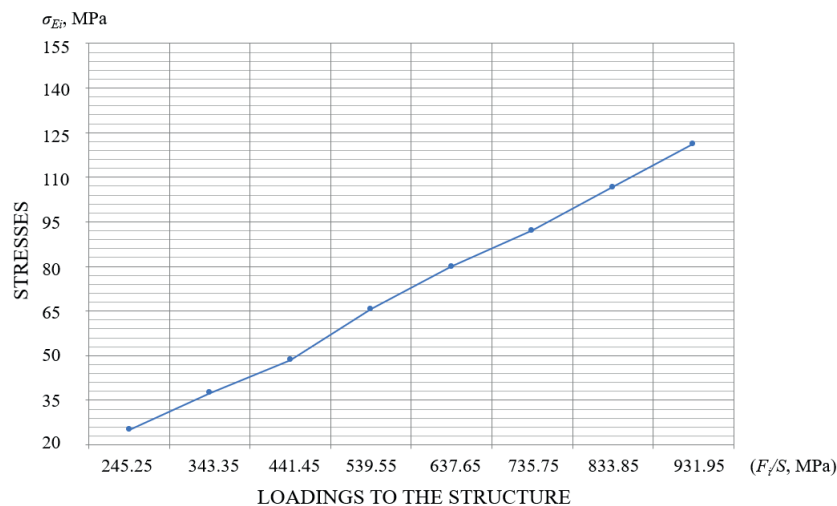


Figure 9 Experimental dependence of output indicators (σ_{Ep} MPa) on the influencing factors (F_i/S , MPa) in test position I at 90°

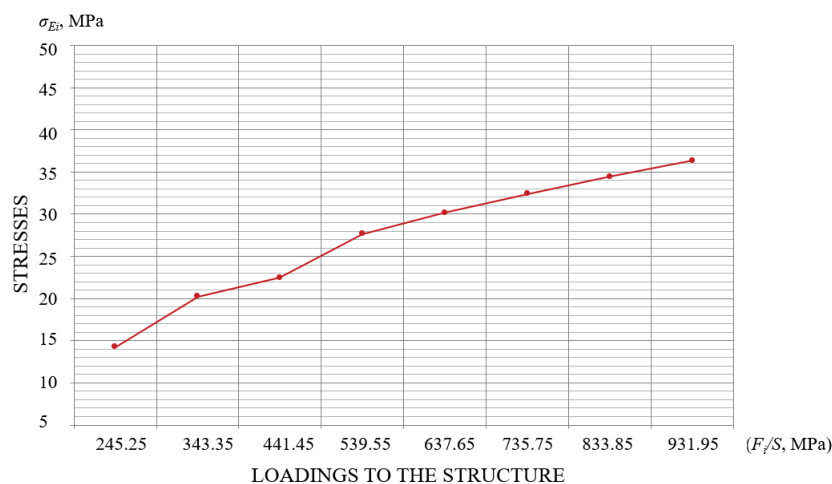


Figure 10 Experimental dependence of output indicators (σ_{Ep} MPa) on the influencing factors (F_i/S , MPa) in test position II at 60°

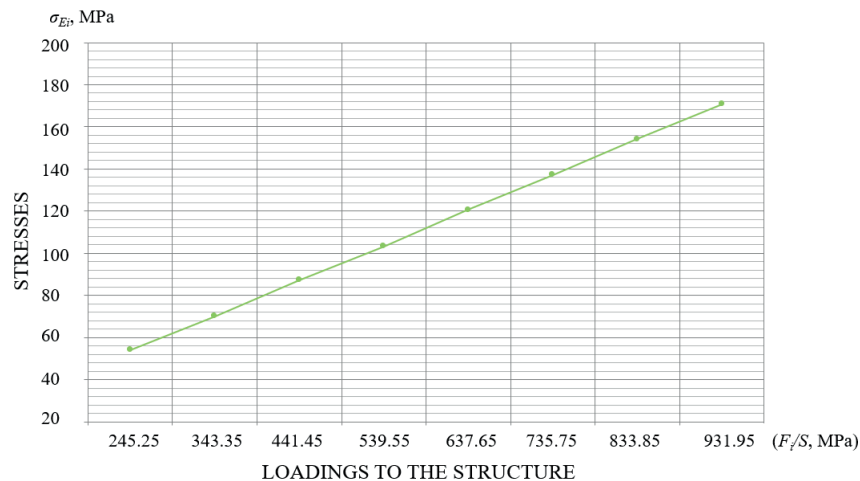


Figure 11 Experimental dependence of output indicators (σ_{Ei} , MPa) on the influencing factors (F_i/S , MPa) in test position III at 30°

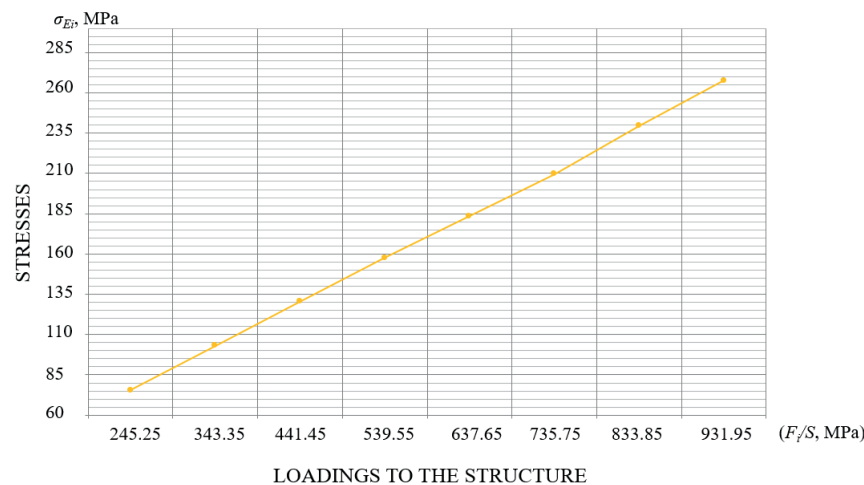


Figure 12 Experimental dependence of output indicators (σ_{Ei} , MPa) on the influencing factors (F_i/S , MPa) in test position IV at 0 degrees

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		
	y_{ei}	y_{thi}	%	y_{ei}	y_{thi}	%	y_{ei}	y_{thi}	%	y_{ei}	y_{thi}	%
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

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 (σ_{Ei} , MPa), which arise in the design

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 (σ_{Et} , 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%.

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