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Development and construction of a mechanized moving platform for human service

Volodymyr Rashkivskyi[1], Mykola Prystailo[2], Bohdan Fedyshyn[3], Iryna Dubovyk[4], Oleksiy Proskurin[5]

[1,2,3,4,5] Kyiv National University of Construction and Architecture,
31 Air Force Ave., Kyiv, Ukraine, 03037,
[1]Rashkivskyi.vp@knuba.edu.ua, https://orcid.org/0000-0002-5369-6676,
[2]prystailo.mo@knuba.edu.ua, https://orcid.org/0000-0003-3151-4680,
[3]fedyshyn_bm@knuba.edu.ua, https://orcid.org/0000-0003-2420-7332,
[4]dubovyk.iv@knuba.edu.ua, https://orcid.org/0000-0001-7444-9159,
[5]proskurin_oh@knuba.edu.ua, https://orcid.org/0000-0003-0220-9652

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Abstract. The purpose of the proposed article is the development and construction of a mechanized mobile platform for serving people, which is caused by the need to increase the safety of the operation of such technical means, in particular, in the case of the need for mass customer service. **The methodology** is based on search, research and creative approaches. The methods of development analysis, patent search, synthesis of technical solutions, simulation modelling was used**. Scientific novelty.** The study of the features of various approaches to the creation of effective mechanized moving platforms, the analysis of solutions and the dynamics of patenting made it possible to substantiate the directions of development of technical solutions and the prospects of developments. The authors proposed constructive solutions for mobile platforms, developed approaches to the technical implementation of increasing the safety of their operation, proposed energy-saving approaches aimed at reducing the energy consumption of mechanized means, which is especially relevant in the mass implementation of platforms for serving people**. Research results.** The article solves important safety issues of human service, in particular in the entertainment industry through the development of structural parts, drives and rules for the operation of mechanized moving platforms. Synthesized constructive solutions obtained in the course of patent research, analysis of modern technical solutions, rational technical design, and expert evaluation are presented. It was determined that the safety of the operation of mechanized moving platforms, which are intended for the transport of people in the field of tourism, depends on effective approaches to the design and components of the technical system in the form of a moving platform, its structural components, elements of its mechanism and the drive system as a whole, which with the optimization of technical indicators the stability of the overall system, the smoothness of movement and braking of the platform, the optimization of the materiality of the structure in total allow to have a qualitative effect on improving the safety of human operation.

Keywords: human service, operational safety, mechanized equipment, platform, energy recovery, sustainability.

INTRODUCTION

The development of mechanized equipment for serving people is highly relevant in the sector of organizing cultural and mass events. Thus, during the organization of concerts of world stars, moving platforms are used, which aim to create spectacle and captivate the audience. At the same time, moving platforms for the audience are widely used to create an additional sense of presence. Platforms that are used as attractions can also be considered objects of study. This paper examines the process of developing and constructing such a platform, taking into account groups of people with limited mobility or children of preschool age. For this, a requirement was established to design the platform itself as low as possible to the ground surface and with a minimum number of stairs.

MATERIALS AND METHODS

Today, effective methods of analysing technical solutions are patent search [1], expert evaluation. The analysis of patent decisions, in particular, allows, in addition to determining the level of technical developments, to conduct an analysis of the economic feasibility of scientific developments and development trends through the study of the dynamics of patenting, geographical affiliation, calendar frequency, affiliation to the applicant.

In addition, for the effective design of the technical components of the generalized system, modern means of simulation modelling were used, including parametric design, 3D modelling, kinetostatic analysis, and structural synthesis.

RESULTS AND DISCUSSION

Works [2] are devoted to the study of rational approaches to the design of technical means.

The authors determined that the main directions of effective design and construction of complex systems can be formed as the total indicators of their components, their optimal joint functioning.

It was also noted that increasing the safety of operation of mechanized means can be solved by effective design of mechanized means, reducing their material capacity, ensuring the smoothness of movement modes of mechanisms, increasing their stability, improving the ergonomics of the entire structure and its components [3].

There are well-known solutions for the moving platform-cabin of the driver of a single-bucket excavator [4].

In this solution, the visibility of the operator increases, which is effectively reflected in the safety indicators of technological operations during the work of the excavator driver.

Mechanized moving platforms intended for serving people also include travelators, escalators, lifting platforms for people with disabilities, etc. [5 - 9].

The main problem during the operation of such mechanized systems is the need for smooth movement modes, which include starting, moving and stopping.

To ensure the smoothness of movement of mechanized moving platforms, as a rule, electric control systems of smoothness of movement are used. In addition, the maximum values of the movement speed of such systems are determined - 1 m/s.

In order to effectively analyse technical solutions aimed at increasing the safety of operation of mechanized moving platforms, we will conduct a patent study.

To search for technical solutions in the database systems of patent solutions, we will define thematic search directions (Table 1).

Using the sources of patent documentation, they conducted a search and analysis of technical solutions to the problem. Based on the search results, determine the relevance of this problem.

Table 1. Search regulation

Search subject	Classes according to the IPC	References
Counterweights	E02F 9/18	«Google Patents»: patents.google.com «Espacenet»: espacenet.com «База патентів України»: uapatents.com
Flywheels characterized by means for changing the moment of inertia	F16F15/31	
Lifting devices; Safety devices	E04G3/32	

Analytical research of technical solutions for mechanized platform was conducted on the basis of a patent search for the period from 2000 to 2023.

To search for patent documentation, information sources from the global Internet were used: "Google Patents" (patents.google.com), "Espacenet" (espacenet.com), "Patent Database of Ukraine" (uapatents.com).

According to the international patent classification, the necessary documentation falls into the class E02F 9/18, B66B 9/08, F16F15/31, E04G3/32 (fig.1-3).

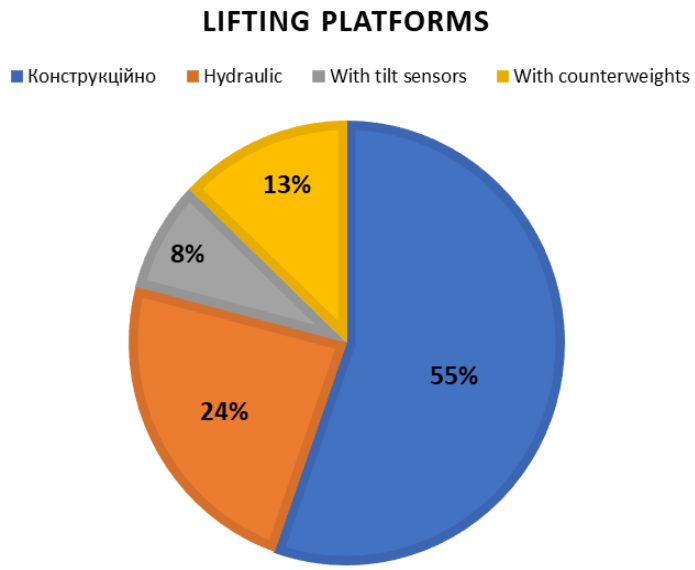


Fig. 1. Result of searching by “lifting platform”

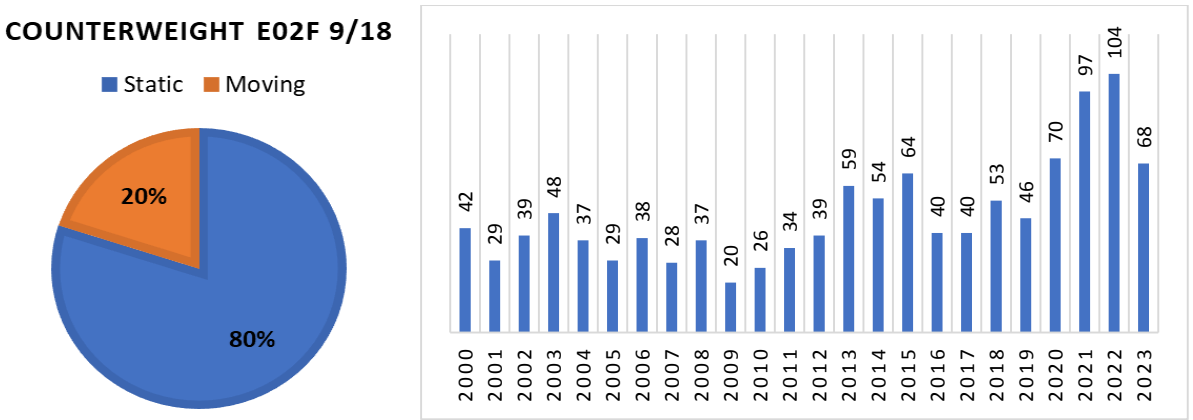


Fig. 2. Result of searching by “counterweight”

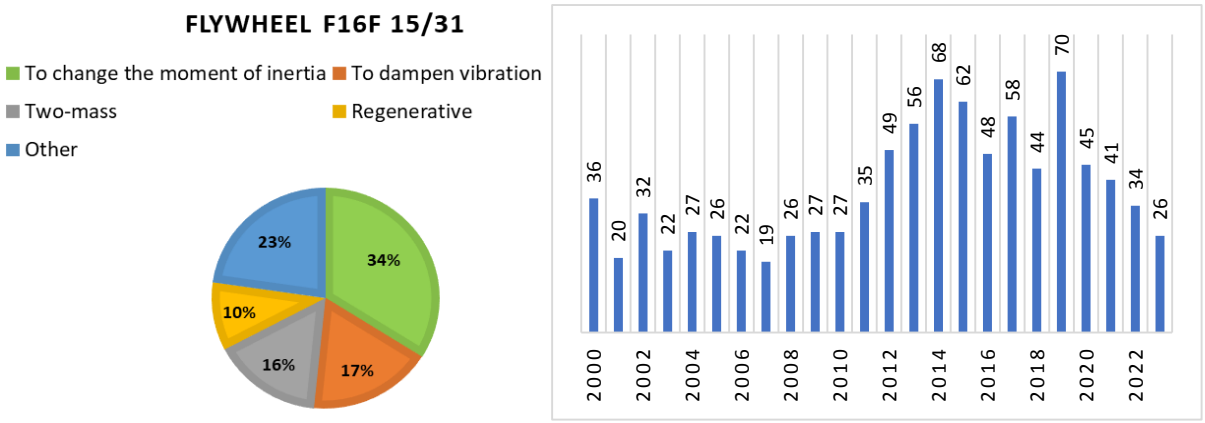


Fig. 3. Result of searching by "flywheel"

During the development of a mobile platform for maintenance, the authors proposed a constructive solution of the mechanized mobile platform (Fig. 4). The proposed mobile platform is intended for use during mass cultural events. The mechanized moving platform is part of a more complex system that forms a carousel attraction. The entire carousel attraction has a weight of 3500 kg, an overall diameter of 7 m, and a height of 4,5 m. The mechanized moving platform has a diameter of 7 m, weight 2100 kg, height of the platform 0,35 m, drive – 5 kW, power from, maximum rotation speed – 1 m/s. The central rack has the following parameters: diameter of 2,1 m, weight 200 kg, height of the platform 2,75 m. The carousel cover has the following parameters: diameter of 7 m, weight 1000 kg, height of the platform 1,35 m.

During the design of the mechanized moving platform and the carousel as a whole, the advisor on creating an accessible environment for people with special abilities, disabilities and other groups with limited mobility was taken into account [5-9].

The carousel is designed with one step for convenient and safe descent or ascent to the platform, the frame and structure of the carousel is shown in Fig. 4.

The mechanized moving platform consists of 5 sections, among which one is drive section, the others are driven. The sections are assembled into a single structure and connected to the power drive. Due to the structural refinement of the supporting wheel [10], the moving platform has a low height of 300 mm. The carrying capacity of one such wheel is 700 kg.

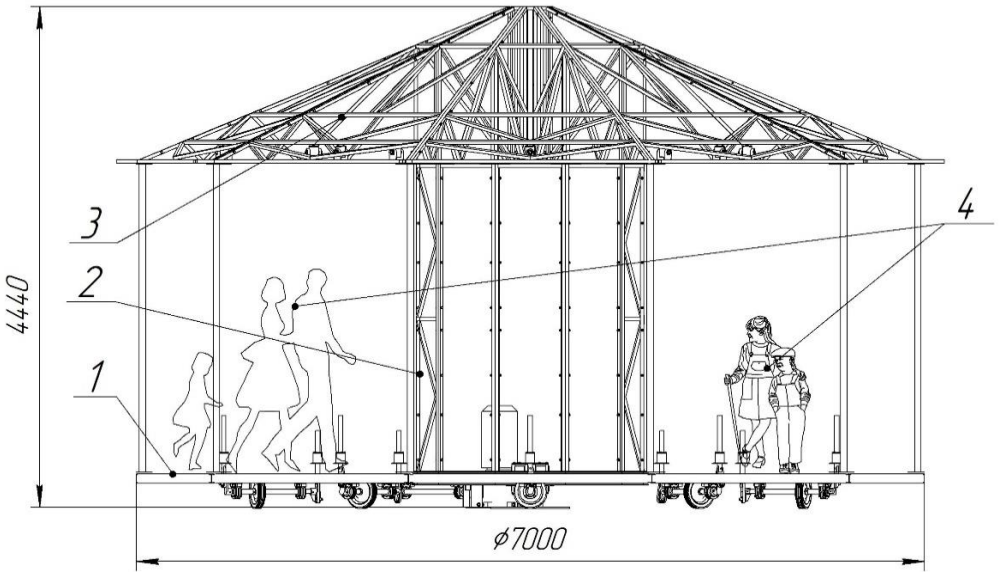


Fig. 4. Construction of the carousel attraction with inclusive access

An important operating condition is ensuring the safety of both staff and visitors. For this purpose, it is necessary: to identify the predicted danger, dangerous events and situations caused by mechanical, electrical, chemical (from raw materials, materials and other substances), thermal (thermal) influence, radiation, water environment, as well as violation of ergonomic requirements and other reasons. Take measures to reduce the risk of accidents and emergency situations [5-9].

The stability of the carousel attraction is an important aspect that affects the safety of its operation. This includes the ability of the attraction to withstand various loads arising during its operation, without the risk of collapse or other dangerous situations [6].

To ensure the stability of the carousel attraction, several key factors must be taken into account.

Construction: The base of the carousel must be strong and stable to withstand the weight and movement of the attraction1. The upper part of the support frame is used to support and mount the superstructure, which rotates along with the rotary table [5].

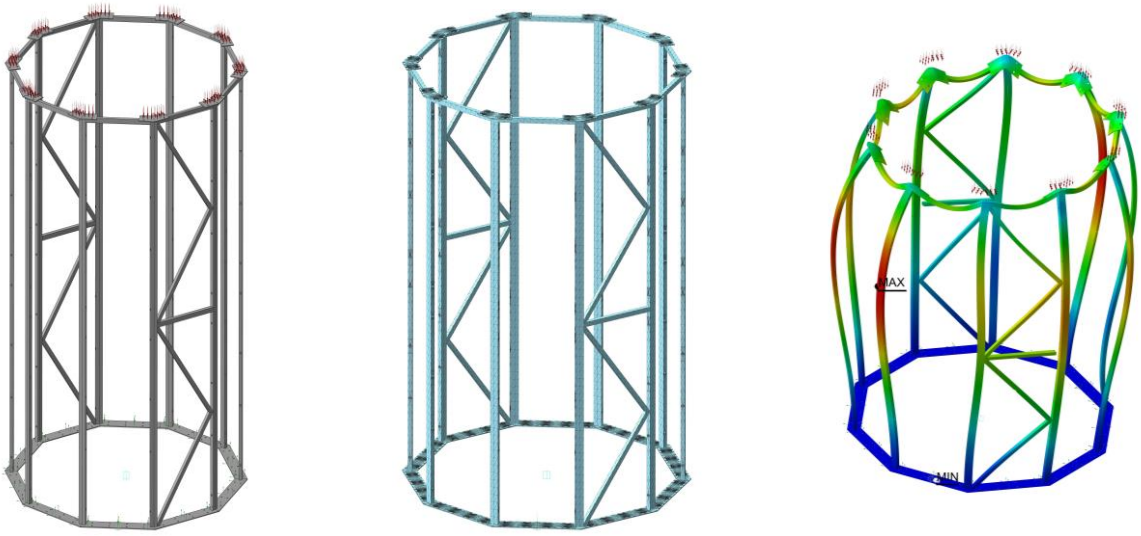
Installation: Correct installation of the attraction is important for its stability. This includes the correct location of the attraction, as well as the installation of all its components according to the manufacturer's instructions [5].

Maintenance and inspection: Regular maintenance and inspection of the ride helps to identify and correct any potential stability problems in the early stages. This may include checking the condition of the materials, joints, base and other important components of the ride [5].

On fig. 5 and table 2 showing the results of modelling the load on the elements of the carousel structures are presented.

Table 2. Characteristic of the model

Name	Value
Types of elements	10- nodal tetraids
Maximum length of the element’s side [mm]	100
The maximum coefficient of condensation on the surface	1,2
Coefficient of rarefaction in the volume	1,5
Quantity of finite elements	250397
Quantity of nodes	498765



a *b* *c*

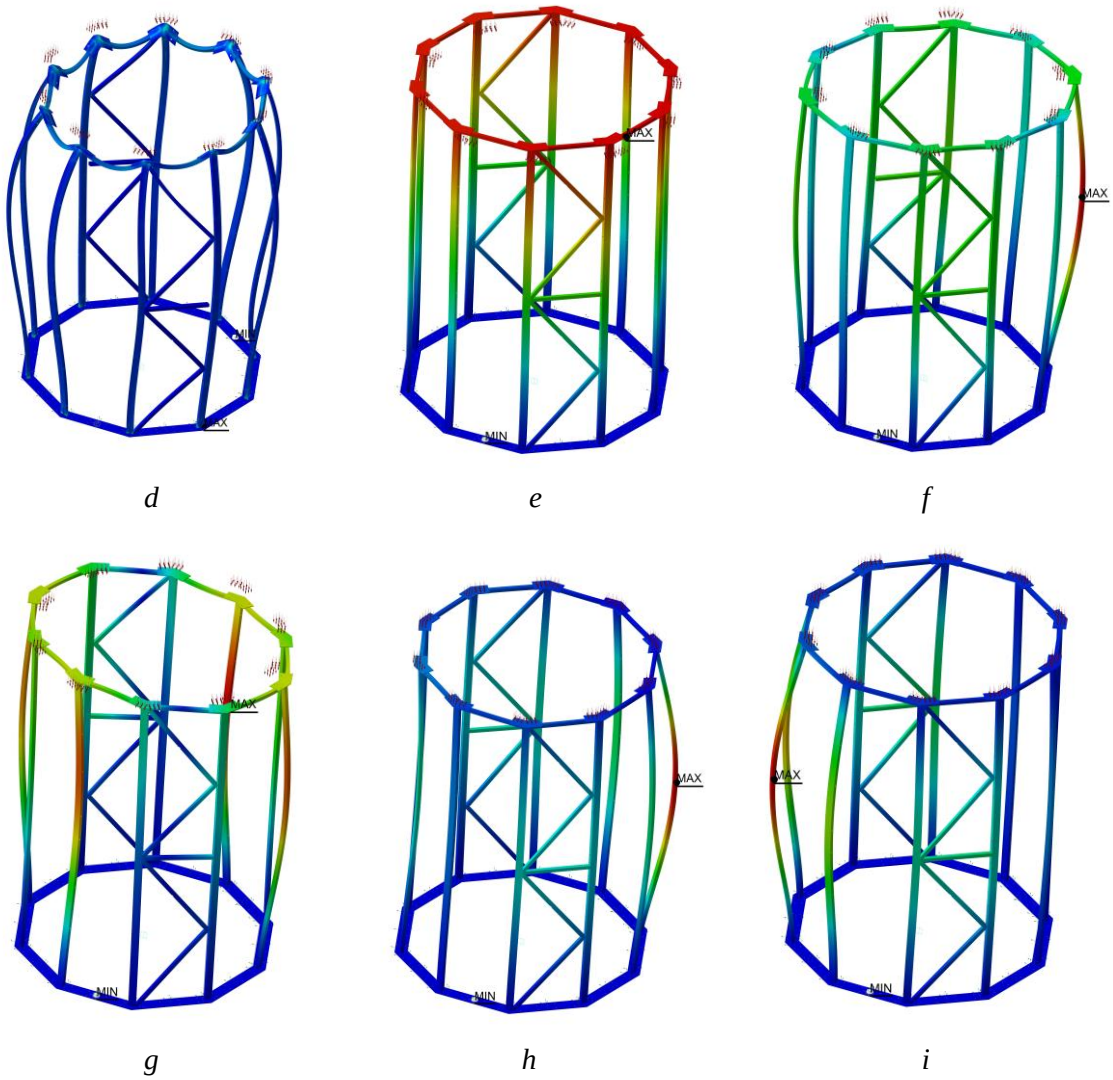


Fig. 5. The results of the strength calculation of the central structure of the carousel:
a – calculation scheme; *b* – grid of finite elements; *c* - total linear movement; *d* - equivalent von Mises stress; *e* - 1st mode of natural vibrations; *f* – 2nd mode of natural vibrations; *g* – 3rd mode of natural vibrations; *h* – 4th mode of natural vibrations; *i* – 5th mode of natural vibrations

Table 3. Inertial model's characteristics

Name	Value
Mass model [kg]	150,17
Center model weight [mm]	(0,071; 1311; 950)
Moment and inertia of the model relative to the center of mass [kg mm ^{2}]	(218438160; 145882246; 214724710)
Reactive moment relative to the center of mass [N mm]	(-1290; 3900; 3842)
Total reaction and resistance [H]	(0; 10000; 0)
Absolutely meaning reactions [H]	1000
Absolute moment value [N mm]	5624

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Table 4. Studied parameters

Name	Type	Min	Max
Mises equivalent stress	SVM [N/mm ^{2}]	0	380
Liquidity reserve factor	SVM	1,440846	10
The margin factor at the strength limit	SVM	2,5	10

Table 5. Natural frequencies of oscillations

N	Frequency [rad/sec]	Frequency [Гц]	Period [c]	мм X [%]	мм Y [%]	мм Z [%]
1	0,0069	0.0011	908	0,646	0.27573	0.214796
2	0,0081	0.0013	779	0.2192	1.07491	0.123159
3	0,0111	0.0018	567	0.2144	0.15635	0.004883
4	0,0124	0.0020	505	0.0662	0.14315	0.154617
5	0,0144	0.0023	438	0.291476	0.01522	0.054812
6	0,0176	0.0028	357	0.004843	0.87856	0.965472
7	0,0193	0.0031	325	0.086432	0.00285	0.221474
8	0,0207	0.003	304	0.000641	0.26934	0.276551
9	0,0217	0.0034	289	0.016833	0.78202	0.031255
10	0,0229	0.0036	274	0.017404	0.00707	0.129765
11	0,0299	0.0047	210	0.082481	0.10908	0.009987
12	0,0395	0.0063	159	0.039919	0.56720	0.038043

By analogy, a strength analysis was performed for the cover of the carousel and the movable lower platform.

Safety: It is important to ensure that all safety standards and procedures are followed, including the use of appropriate safety equipment and regular safety training for staff [7].

Personnel training: All persons participating in the operation of attractions, depending on their duties, must be trained and know the basic technical characteristics, structure and rules of safe operation and maintenance of attractions [7].

These steps will help ensure the stability of the carousel attraction and make it safe to use. In order to ensure the safety of the amusement equipment, the identification of predicted danger, dangerous events and situations caused by mechanical, electrical, chemical (from raw materials, materials and other substances), thermal (thermal) influence, radiation, water environment, as well as violation of ergonomics requirements must be carried out and other reasons [7].

To ensure the stability of the carousel, it is proposed to create a balancing mechanism of automatic action, a movable counterweight.

A movable counterweight is installed under the platform and due to the movement of the load will stabilize the attraction. The system is automatic without operator intervention.

The stability of the carousel is the ability to resist external loads, including the gravitational forces of the weight of visitors on the ground, as well as the component parts of the carousel, inertial forces that prevent the system from destabilizing and moving the supporting part of the carousel relative to the ground base.

The stability of the carousel can be characterized by the coefficient of stability where is the moment of all the forces holding the carousel; is the moment of all the forces contributing to the destabilization of the carousel.

Adjustment of the departure of the counterweight is carried out due to the equalization of the moments of the weight and the moving counterweight relative to the edge of the overturning (tilting) forces. A carousel is considered balanced if the sum of moments is zero. Thus, we will get a system in which, when the

load on the carousel changes, the counterweight is advanced or retracted depending on the information sent by the control and control sensors.

Position sensors are connected to the hydraulic cylinders of the extension beams. The output signal from the control unit is a signal that goes to the proportional distributor, the output of which is connected to the inputs of the counterweight hydraulic cylinders. The control unit continuously receives data on the position and weight of the load - to determine the overturning edge.

The movable counterweight in automatic mode, through the control unit, which continuously receives information, stabilizes the system and balances the carousel [11, 12]. This system will minimize the load on the main components such as the center support, upper bearing, lower linear bearing and reduce the load on the wheels.

Stability, stabilization of the carousel, minimization of distortion of the main components during operation increases the durability of these parts and makes the mechanism as safe as possible.

The principle of movement of the movable counterweight of automatic action is shown in fig. 10.

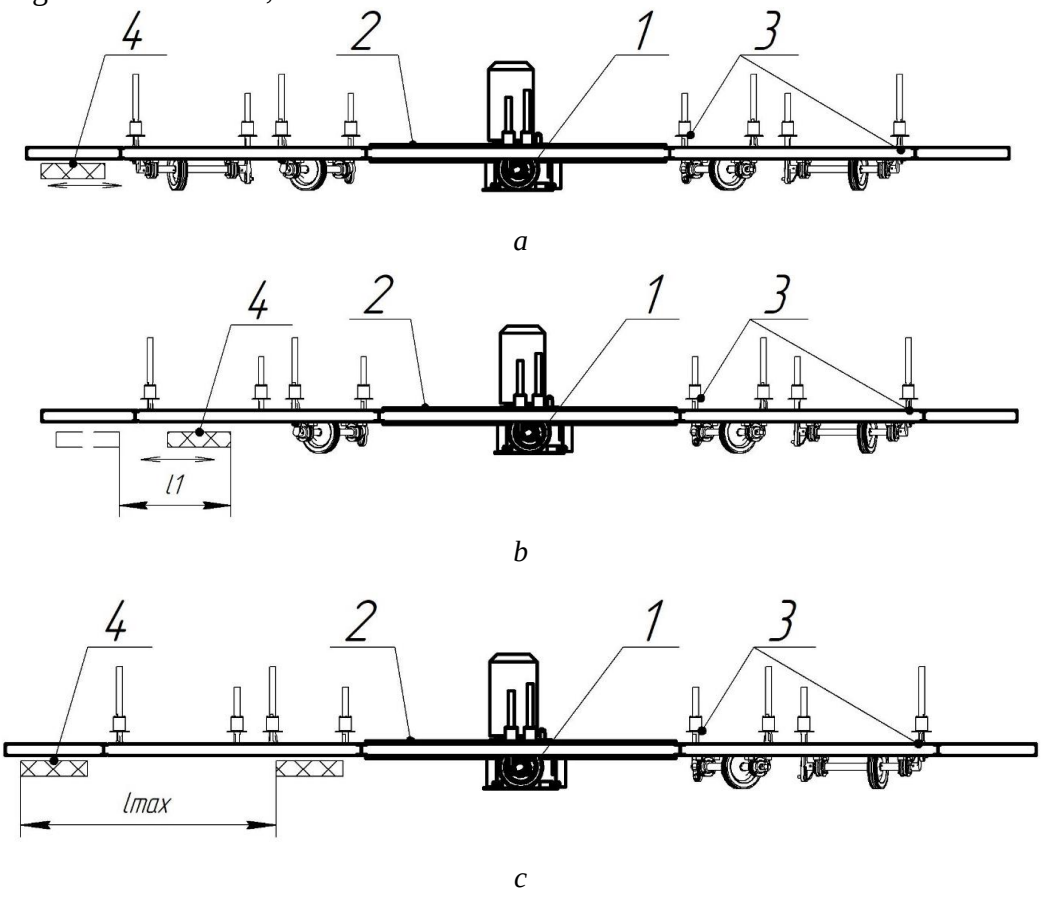

Fig. 6. The principle of operation of the stabilizing mechanism of the counterweight of automatic action: *1* – external load on the platform; *2* – central support; *3* – mass of the movable counterweight; *4* – the line of motion of the movable counterweight: *a* – the movable counterweight is maximally extended from the central support; *b* – average counterweight position; *c* – movable counterweight at rest, located as far as possible to the central support.

The principle and example of the system of maintaining the stability of the carousel due to the moving counterweight is shown in fig. 7.

When the mechanism is at rest and does not have excess loads on the main components, such a system is called balanced, that is, the sum of the holding and overturning level is 0 (Fig. 6. a).

During the external load on the carousel mechanism, the movable counterweight compensates for the excess load on the main components.

The movable counterweight system reacts to the excess load and pushes or pushes the movable counterweight away from or towards the central support (Fig. 6. *b*, *c*).

Emergency response of the moving counterweight system to the failure of the braking system or the failure of the main components, which affect the safety of visitors and personnel (Fig. 6. *d*). Due to the conservation of energy and inertia of the mass of the moving counterweight, it is possible to reduce the rotation speed of the carousel.

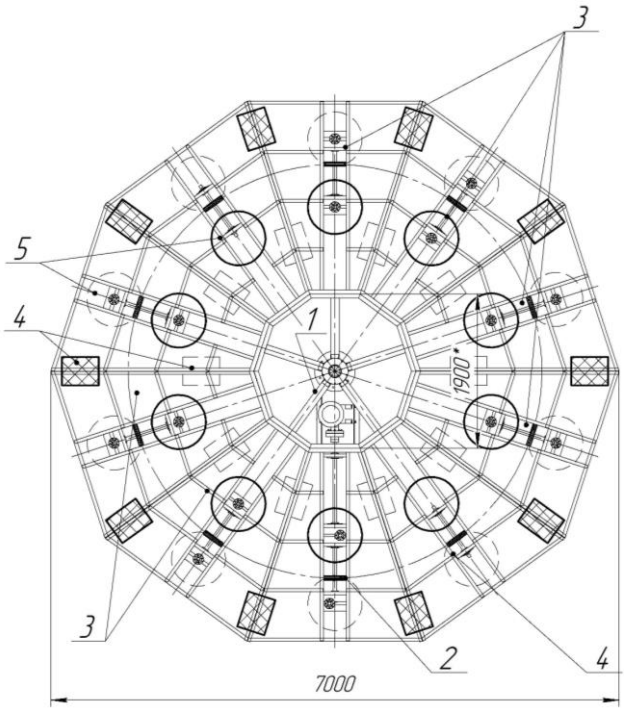

Fig. 7. The principle of operation of the carousel stability maintenance system due to the movable counterweight: *1* – central base; *2* – drive section; *3* – moveable section; *4* – moving counterweight; *5* – mass loading places

The implementation of new solutions in the constructions of the moving platform requires further consideration of the concentration of new force influences in the calculation model. And the implementation of the safe movement of such a platform requires simulation of transient processes at the moment of movement/stop of the platform, taking into account the synthesized solutions for the design of the drive part of the platform [8-10].

CONCLUSIONS

The development and construction of mobile platforms for serving people is an actual direction that solves the needs of people in various directions, in particular, the organization of cultural and mass events. At the same time, solving the problems of the mechanization of such platforms is a broad direction that requires patent research, taking into account specific safety standards of structures and operation, synthesis of technical solutions and modelling of the behaviour of structures.

For a moving counterweight, it is necessary to optimize the inertial and speed parameters taking into account the parameters of the platform as a whole.

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Розробка та проектування механізованої рухомої платформи для обслуговування людей

Володимир Рашківський[1], *Микола Пристайло*[2], *Богдан Федишин*[3], *Ірина Дубовик*[4], *Олексій Проскурін*[5]

[1,2,3,4,5] *Київський національний університет будівництва і архітектури*

Анотація. Метою запропонованої статті є розробка та конструювання механізованої мобільної платформи для обслуговування людей, що викликано необхідністю підвищення безпеки експлуатації таких технічних засобів, зокрема, у разі необхідності масового обслуговування клієнтів. В основу методології покладено пошуковий, дослідницький та творчий підходи. Використано методи аналізу розвитку, патентного пошуку, синтезу технічних рішень, імітаційного моделювання. **Наукова новизна.** Дослідження особливостей різних підходів до створення ефективних механізованих рухомих платформ, аналіз рішень та динаміки патентування дозволили обґрунтувати напрямки розвитку технічних рішень та перспективи розробок. Авторами запропоновано конструктивні рішення мобільних платформ, розроблено підходи до технічної реалізації підвищення безпеки їх експлуатації, запропоновано енергозберігаючі підходи, спрямовані на зниження енергоспоживання механізованих засобів, що особливо актуально при масовому впровадженні платформ для обслуговування людей. **Результати дослідження.** У статті вирішено важливі питання безпеки обслуговування людей, зокрема в індустрії розваг, шляхом розробки конструктивних елементів, приводів та правил експлуатації механізованих рухомих платформ. Наведено синтезовані конструктивні рішення, отримані в ході патентного пошуку, аналізу сучасних технічних рішень, раціонального технічного проектування та експертного оцінювання. Визначено, що безпека експлуатації механізованих рухомих платформ, які призначені для перевезення людей у сфері туризму, залежить від ефективних підходів до проектування та складових технічної системи у вигляді рухомої платформи, її конструктивних вузлів, елементів її механізму та системи приводу в цілому, які при оптимізації технічних показників стійкості всієї системи, плавності руху та гальмування платформи, оптимізації маневреності конструкції в цілому дозволяють якісно вплинути на підвищення безпеки експлуатації людини.

Ключові слова: обслуговування людей, експлуатаційна безпека, механізоване обладнання, платформа, рекуперація енергії, стійкість.