Simulation modeling of the lifting and assembly module of the supports of the structural coating

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Abstract. The materials of the article are devoted to the issue of simulation modeling of construction mechanized technological equipment, in particular, modeling of the lifting and assembly module for the installation of a structural coating. Today, an urgent task in the construction market is the construction of large-scale structures, the life cycle of which is shortened, but the construction terms are reduced. Such a need exists in the construction of shelter hangars, field hospitals, warehouses, etc. As a rule, for urgent needs, buildings with light construction structures are erected, the covering of which is formed by structural blocks. A feature of such structures is multi-element support elements. A lifting assembly module is proposed for the installation of such structures.

It is essential that the mounted structural coating is assembled on the heads of the lifting and collecting modules in blocks, and the lifting of the structural block to the design mark occurs thanks to the module while simultaneously raising/assembling the supporting elements of the coating. Simulation computer modeling tools were used to study the possibility of implementing the assembly process using the lifting assembly module. It is proposed to use the parametric formation of sketches and 3D models when forming the design features of the module. The dissection of the elements of the new assembly module, support elements and structural coating to the level of simple parts made it possible to determine their mass characteristics with sufficient accuracy. The basic technical indicators of the assembly module and building structures, which can be used in the development of the assembly technology, were obtained.

Approaches to the use of cloud databases when using unified elements during design are defined. The use of simulated geometric modeling data allows to analyze the strength properties of the components of the technical system and, together with the visual observation data, to create a common information model of the building object with the possibility of qualitative analysis of the indicators of the specified elements of building structures.

Keywords: lifting and assembling module, structural coating, modeling.

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INTRODUCTION

Today, the construction of light constructions is relevant. Such needs are the need for short-term placement of groups of people, equipment, materials and goods in areas affected by external aggressive factors (military operations, placement of COVID-19 centers, logistical supply of goods, etc.). As a rule, for this, construction objects are created from light metal structures. There is a need to develop mechanized complexes for the installation of such construction objects, and in case of their disappearance, their actualization, simple dismantling [9, 10, 18].

The purpose of the work is to develop a simulation model of a lifting-assembly module for the installation of a structural coating.

At the department of construction machines and construction technologies of the KNUCA, was developed a model of a load-lifting module for the installation of a structural coating, which ensures an effective improvement of the installation technology at a construction site [4].

PRESENTING MAIN MATERIAL

The lifting and assembly module (LAM) is designed for lifting the block of structural covering for the installation of columns. It consists of a frame, inside which the installation zone is formed. The main parameters for the design of the LAM are the dimensions of the column, the weight of the structural covering block, and the dimensions of the spans and steps between the columns. The weight of the structural covering block does not exceed 20 tons, and the cross-section of the column is 500...700 mm. The size of the spans is 24, 30, 36 m, and the steps are 12, 15, 18, 24 m. In accordance with the determined parameters of structures and buildings, as well as the characteristics of hydraulic cylinders, the column is divided into component parts. The height of the components is 1200 mm [2].

Structurally, the LAM represents the following scheme: in the upper part of the module there is a support head on which the lifting load is installed. The raising/lowering of the structural covering block occurs when using the number of modules in accordance with the number of supports of the structural covering according to its design features. In our case, the minimum number of LAM per block is 4 pcs (Fig. 1).

When developing new means of installation, methods and devices, it is impossible to clearly formulate the technical task, since its final version may change during the research.

At the same time, simulation modeling methods are used to study the installation process.

For simulating the installation of a structural coating and the mechanisms for its implementation, it is advisable to use a powerful modern toolkit – parameterized design [1]. This makes it possible to create three-dimensional models of components of technological equipment and assembled structures with unexpressed and dependent dimensions, to create a certain database of them for the automated formation of form-forming sketches of components of an assembly unit or the geometry of individual parts of newly created structures [11].

The software capabilities of parameterized design allow you to change the geometric dimensions of the form-forming sketch of the part, the parameters of the three-dimensional forming of the part, the mutual placement of parts in the assembly unit, the number of parts in the assembly unit, and much more during

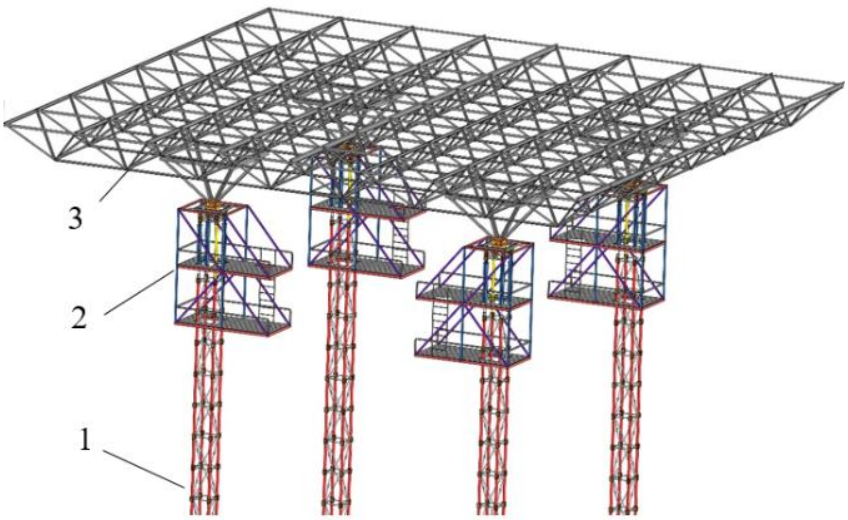


Fig. 1. The scheme of placement of LAM on the supports of the structural covering: 1 – column; 2 – LAM; 3 – structural covering unit

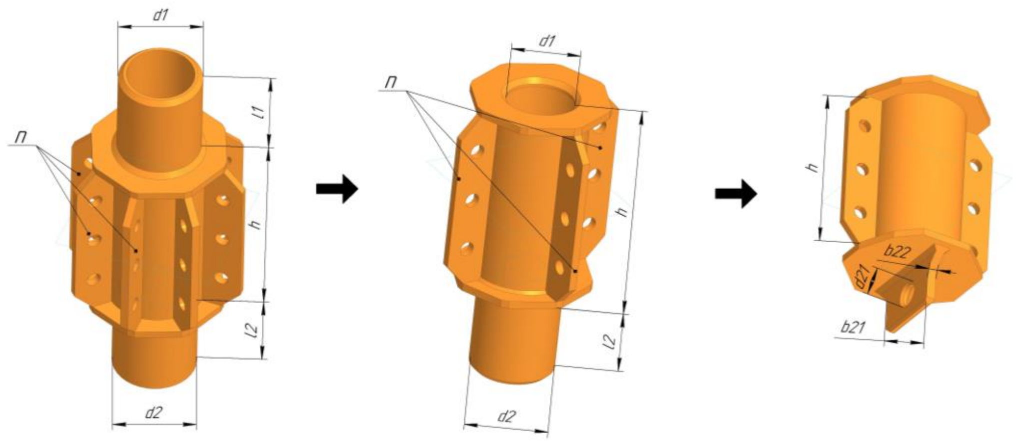


Fig. 2. An example of the use of implicitly expressed geometric data for a support coupling of a structural coating: *d1* – diameter of the upper connection; *l1* – the length of the upper connection; *h* – height of the lower connection; *d2* – diameter of the lower connection; *l1* – coupling height; *d21, b21, b22* – variable parametric dimensions of the lower connection; *n* – the number of connection bars

the modeling process.

In Fig. 2 shows an example of the application of parametric data for supporting structural elements of the structural coating.

It should be noted that in the case of parameterized design, it is possible to easily change the number of structural elements in the module (for example, *n* in Fig. 2). It is also possible to define "important" dimensions for the further assembly unit and "not quite important" ones, which, for example, relate to the shape, number of holes, diameters of the bar *n* in Fig. 2.

In order to understand the necessary accents during the assembly of simulation models, it is necessary to have constant feedback with the modeling object, its constructive and technological features.

Also, let's return to the consideration of the technical features of the cargo-lifting module.

The load-lifting module is installed in the installation area of the columns in such a way that the center of its installation area coincides with the center of the column. First, the lower support element of the column is installed and fixed to the foundation support plate with anchor bolts and welding [4]. The first tier of the column is installed on the support head (Fig. 3) The component columns are presented in the form of rolled pipes, which allow, when connecting them with couplings, to use quick-removable mounting devices, for example, those used in formwork systems [2, 7, 12].

Column sections are connected to each other by transverse and diagonal ties, aligned and fixed.

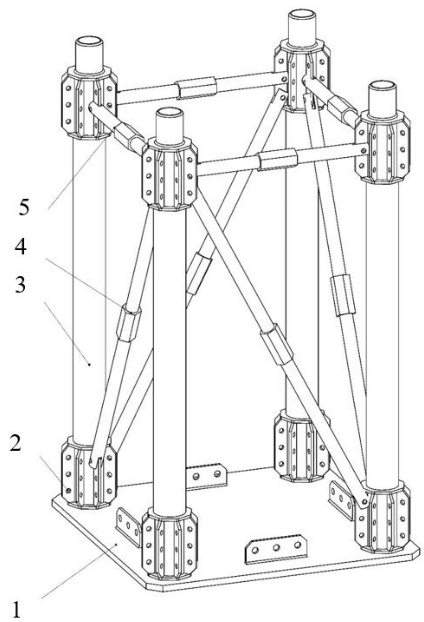


Fig. 3. Construction of the support part of the column: 1 – support plate (header under the column); 2 – clutch; 3 – column section; 4 – diagonal ties; 5 – transverse ties

After that, the upper couplings are installed, which are fixed on the column sections, and the load-lifting module is placed vertically above the support head (Fig. 4). On top of the head of the module, the lower support part of the structural covering is installed, in the form of an inverted pyramid. In the lower part of the LAM there are platforms. Sub bridges can be independent or connected between LAM within the same block of coverage.

The installation of the structural block of the covering together with the crane, plumbing, electrical equipment and the roof takes place immediately on the support nodes that are installed on the LAM.

To ensure the stability of the structural block of the covering during the extension of the column sections, the use of a scheme of three power hydraulic cylinders and a permanent support is proposed. Such a scheme forms a rectangular prefab column in cross-section and allows obtaining during the installation of the components of the column three minimum possible support points, which allows to ensure stability during installation.

The installation of the tier of the structural covering column is as follows.

For one block of structural covering, it is necessary to provide such a number of LAM that will correspond to the structural scheme of the building and ensure the stability of the structural covering. The minimum number of LAM for lifting the structural covering block is 4 pcs.

Simulation modeling of the structural coating, supports and cargo-lifting module made it possible to obtain their indicators (Table 1).

It is necessary to ensure the constant availability of power for the LAM hydraulic drive system as well as the installation accuracy control system.

An effective modern toolkit is the use of open databases of three-dimensional models [15], in which manufacturers place 3D models under the rights of free use. This approach allows you to focus only on individual components for simulation modeling at the project stage.

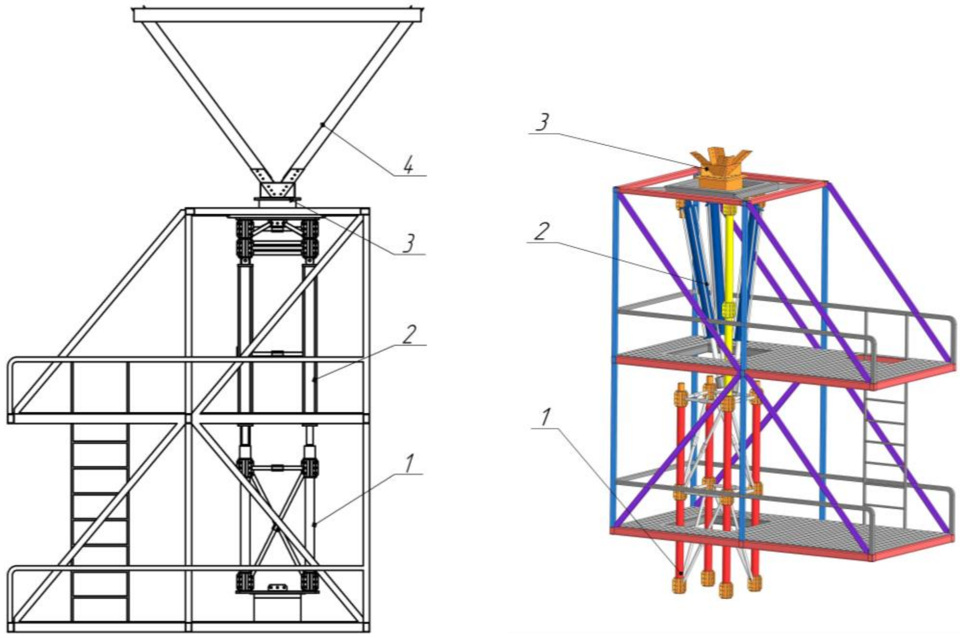
Table 1. Technical characteristics

№	Name element's	Index
1	**Structural coating (block)**	
	Dimention, m	24×24×1,6
	Weight, tonn	12
	Moments of inertia	
	In the absolute coordinate system:	
	Axial moments of inertia	
	Jx, kg·m^2	2446242.22
	Jy, kg·m^2	2228377.26
	Jz, kg·m^2	2228377.26
	Centrifugal moments of inertia	
	Jx, kg·m^2	-1725398.99
	Jy, kg·m^2	-6473001.68
	Jz, kg·m^2	6804127.63
	In the main central coordinate system	
	J1, kg·m^2	1200983.67
	J2, kg·m^2	616810.34
	J1, kg·m^2	593486.68
2	**Support column**	
	Height, m	1,2
	Size, mm	700×700
	Weight, ton	1,5
	Number of component blocks	9
3	**Lifting and assembly module**	
	Quantity	4
	Size, m	4,5×4,0×2,0
	Weight, tonn	1,8
	Power, kV	7,5
	Speed, m/sec	0,01

A useful feature of such services is the software possibility of using a 3D model in the desired format.

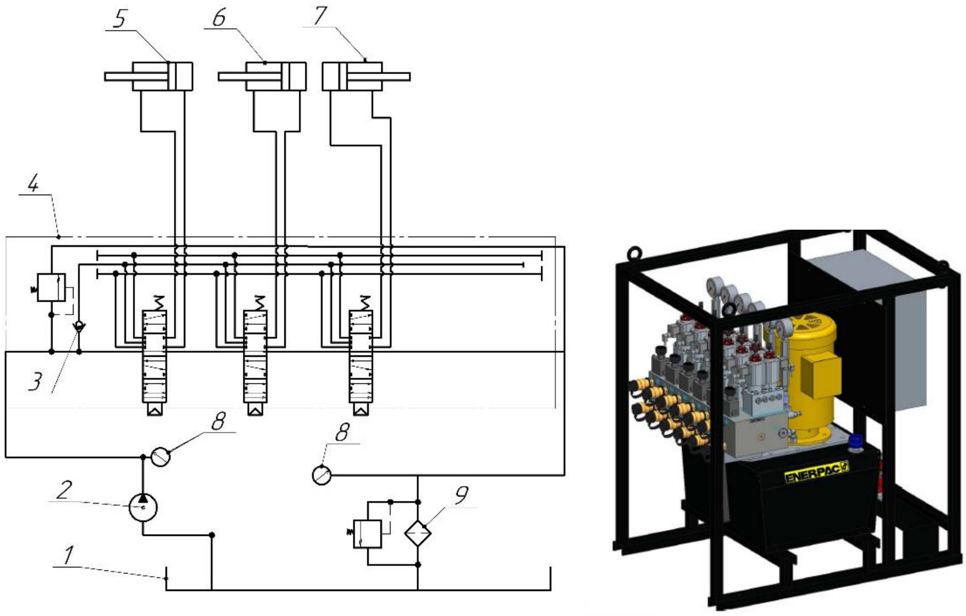
Let's return to the description of the lifting and assembling module/

The automated hydraulic complex is installed on LAM platforms and consists of a central control unit, a pumping unit (4 pcs.), hydraulic mains, power hydraulic cylinders (3×4 pcs.). The central control unit consists of collectors, synchronizers, a system with special software, a set of communication cables, and a signal repeater [6].



a *b*

Fig. 4. Lifting and assembly module: a – side view; b – axonometric view: 1 – column tier; 2 – lifting and assembly module; 3 – column head; 4 – support node structural covering



a *b*

Fig. 5. The automated hydraulic complex: *a* – hydraulic scheme; *b* – import 3D model of pump station: 1 – tank with liquid; 2 – pump; 3 – non-return valve; 4 – control unit; 5, 6, 7 – power hydraulic cylinders; 8 – manometer; 9 – security group

The remote control is used at the facility to control hydraulic oil stations in the amount of 4 pcs., hydraulic cylinders in the amount of 12 pcs. The voltage for the control system is 220 V. The hydraulic control scheme of the pumping unit is shown in Fig. 5.

In order to achieve high accuracy of moving heavy objects, it is necessary to control and synchronize the movement of several lifting points. Microprocessor control uses the signal coming from numerous sensors to control the spatial position of any large, heavy or complex structures, regardless of their weight distribution [7].

By changing the oil supply in each cylinder, the system controls the position very precisely. By eliminating the need for manual intervention, this control ensures structural integrity and increases lifting productivity and safety [13].

Microprocessor controlled synchronous lifting systems reduce the risk of bending, twisting, tension or skewing between the marking points due to uneven distribution of weight or loads. The system uses displacement sensors that provide feedback to the control system. Sensors are attached with magnets and connected by cables.

Hydraulic power station supplies the 7.5 kW for the hydraulic cylinders. The technical characteristics of the hydraulic electric station 7.5 kW are given in the Table 2.

By using parametric geometric design, we can say that the obtained geometric model has the properties of rapid changes in its geometric parameters, which is very important in the course of modeling the newly created system.

An important stage of simulation modeling is the study of the strength properties of individual elements and the system.

An effective means of researching a new system is the use of a research method based on the creation of models of finite elements [16, 17].

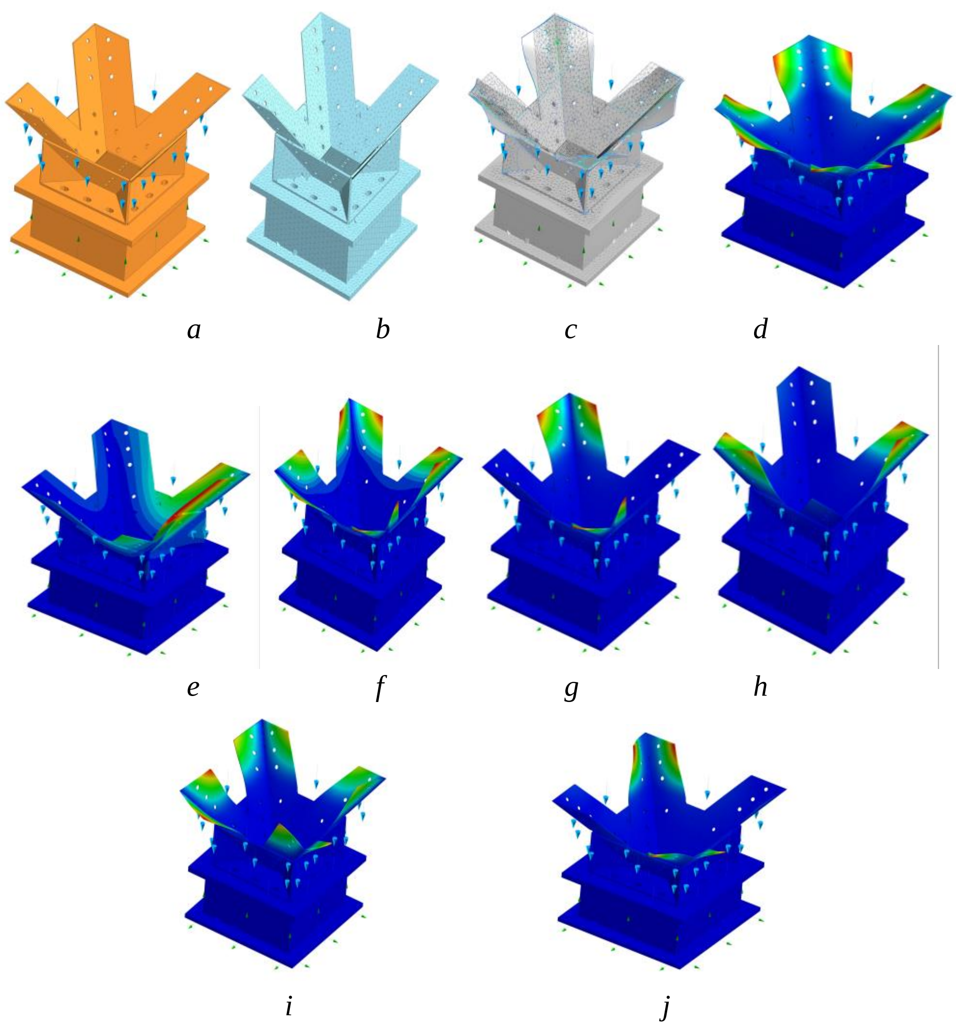


Fig 6. Example and result of simulation modeling of a support element of a column: *a* – supporting element, 3D model; *b* –finite element model; *c* – equivalent tension; *d* – total linear displacement; *e* – 1-st form of buckling; *f* – 1-st waveform; *g* – 2nd waveform; *h* – 3rd waveform; *i* – 4th waveform; *j* – 5th waveform

Table 2. Technical characteristics of the hydraulic electric station

Name	Indicator
Operating voltage and frequency	AC380V 50
Capacity , kV	7,5
Nominal pressure, MPa - low - high	70 10 70
Nominal feed, l/min - low - high	 30 6,3
Tank capacity, l	100
Weight, kg	140

For computer models, sufficient detailing of the research system and determination of external influences on it is important.

In Fig. 6 an example of modeling internal loads on the support section of the structural coating is given.

It is important to note that in case of exceeding the allowable stresses in the intersections of structural elements, it is possible to automatically make changes in the geometry of form-forming sketches, models, etc.

A practical study of the created system, in particular a complex of load-lifting modules for the installation of a structural coating with supporting elements, consists in monitoring the deviations of the base points during its operation [13, 14].

For visual control of installation operations, it is suggested to use the high-precision measurement complex. The measurement complex includes receiving devices; high-precision electronic robotic tacheometers; prisms and marks mounted on the structures of the arch, stiffening beam, and around them to determine the design position of the stiffening beam and its change; communication and computer equipment, as well as software for managing the complex (Fig. 7) [5, 8].

According to this scheme, one or more tacheometers monitor the readings of the control points, which are placed in the nodes of the structures and in the reference points. In addition, beam roll measurements are performed using tilt sensors.

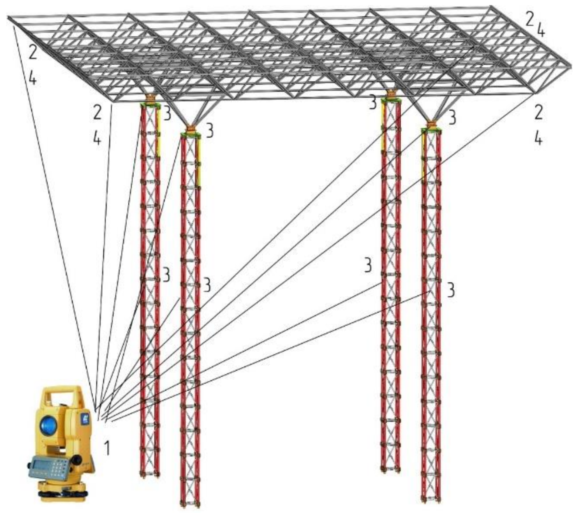


Fig. 7. Scheme of an automated complex for high-precision measurement of installation deviations: 1 – tacheome-ters; 2 – GPS receiving device; 3 – control points (benchmarks); 4 – tilt sensors

Since the system "structural cover – structural supports – load-lifting module" is a dynamic system, the change in the position of the structural cover can be influenced through the parameters of the load-lifting module. During practical research, this means that in case of deviations of the base points from the design, the values of the deviations can be interpreted into commands for the power drive of the cargo-lifting module, actually check it in automatic mode, having previously created the appropriate information system [7, 12].

Today, effective methods of monitoring construction works, especially installation, are the use of UAVs along with methods of creating three-dimensional models by processing photogrammetric data [8]. Monitoring systems allow you to obtain an accuracy of up to 50 mm, which does not quite meet the construction requirements for installation accuracy, however, they provide an opportunity to obtain relative data with differentiation in time, which makes it possible to analyze the installation process, or when changing technical equipment UAV, for example, an infrared camera, to receive tempera-tour pictures of the work site, etc. [19, 20].

The specialized software constantly compares the obtained results with the design data and displays the values of the deviations using graphs and tables on the operator's display [11, 12].

CONCLUSIONS

1. The lifting and assembly module designed for lifting the structural cover block for the installation of columns is developed. It consists of a frame, inside which an installation zone is formed.

2. A scheme of the installation of the tier of columns and the dismantling of the LAM has been developed. If necessary, the dismantling of the columns with the lowering of the SPP takes place in the reverse order. According to the suspension scheme and dimensions of the structural cover block, the characteristics of the power hydraulic cylinders and the hydraulic system are determined.

3. Determined parameters of the components of the lifting and assembly module to take them into account when developing a construction project.

4. Geometric modeling allows us to use the obtained data to analyze the strength properties of the components of the technical system and, together with the data of visual observation, to create a joint information model of the building object with the possibility of qualitative analysis of the indicators of the specified elements of building structures.

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Имитационное моделирование подъемно-сборочного модуля для монтажа структурного покрытия

Владимир Рашкивский

Аннотация. Материалы статьи посвящены вопросу имитационного моделирования строительной механизированной технологической оснастки, в частности моделированию подъемно-сборочного модуля для монтажа структурного покрытия. На сегодняшний день, актуальной задачей на строительном рынке является строительство крупногабаритных сооружений, жизненный цикл которых сокращен, однако сроки возведения уменьшены. Такая потребность существует при возведении ангаров укрытия, полевых госпиталей, складских помещений и т.д. Как правило, для срочных нужд возводят здания с легкими строительными конструкциями, покрытия которых образуют структурные блоки. Особенностью таких конструкций есть многоэлементность опорных элементов. Для монтажа таких конструкций предложен подъемно-сборочный модуль.

Существенным при этом является то, что монтируемое структурное покрытие собирается на оголовках подъемно-уборочных модулей в блоках, а подъем структурного блока к проектной отметке происходит благодаря модулю при одновременном подравивании/сборке опорных элементов покрытия. Для исследования возможности реализации процесса монтажа с помощью подъемно-сборочного модуля использованы средства имитационного компьютерного моделирования. Предложено при формировании конструктивных особенностей модуля использовать параметрическое формирование эскизов и 3д моделей. Расчленение частей нового монтажного модуля, опорных частей и структурного покрытия до уровня обычных деталей позволило найти их массовые свойства с достаточной точностью. Получены базовые технические характеристики монтажного модуля и строительных конструкций, которые могут быть использованы при разработке технологии монтажа. Определены подходы к применению облачных баз данных при использовании унифицированных элементов в ходе проектирования. Использование данных имитационного геометрического моделирования позволяет провести анализ прочностных свойств составляющих технической системы и вместе с данными визуального наблюдения создать общую информационную модель строительного объекта с возможностью качественного анализа показателей определенных элементов строительных конструкций.

Ключевые слова: подъемно-сборочный модуль, структурное покрытие, моделирование.