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Analysis of the principles of working load formation in power drives of construction machines and equipment

Alla Yesipenko[1], Volodymyr Rashkivskyi[2], Yuri Zaiets[3]

[1,2,3] Kyiv National University of Construction and Architecture,
31 Air Force Ave., Kyiv, Ukraine, 03037,
[1] yesypenko.ad@knuba.edu.ua https://orcid.org/0000-0003-0460-2749 ,
[2]rashkivskyi.vp@knuba.edu.ua, https://orcid.org/0000-0002-5369-6676,
[3]zaiets_yv@knuba.edu.ua – http://orcid.org/0000-0002-9711-042X,

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Abstract. The purpose of the proposed article is the analysis of the principles of the formation of the workload on the executive bodies of construction machines and technological equipment, which is due to the need for their improvement in order to improve the energy and technological indicators of technological processes.**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 various approaches to ensuring the implementation of the working movements of executive bodies of construction machines and mechanized technological equipment, the analysis of technical solutions allowed to substantiate the directions of development of drives of construction machines to ensure the necessary laws of movement of executive elements. The authors proposed constructive solutions for synthetic drives of construction machines and equipment, proposed energy-saving approaches aimed at reducing energy consumption. **Research results.** The article deals with important issues of analyzing the formation of loads on executive bodies of construction machines and equipment. Synthesized constructive solutions obtained in the course of patent research, analysis of modern technical solutions, rational technical design and expert evaluation are presented. A technical solution is proposed to ensure the implementation of adaptive feed in a hydraulic power drive, which can be used in the modernization of existing drives of construction machines and moving parts of mechanized technological equipment.

Keywords: workload, mechanized technological equipment, construction equipment, productivity, optimization.

INTRODUCTION

Justification of the importance of optimal formation of the workload for increasing the efficiency of construction processes, reducing costs and improving the quality of work is an urgent task [1].

The purpose of the work is to analyze approaches to determining the optimal workload of mechanized technological equipment.

Object of research. Executive working bodies of construction machines and mechanized technological equipment.

Subject of research. Processes of forming the workload on executive working bodies of construction machines and moving parts of mechanized technological equipment.

To determine the principles of forming the load on the working bodies of machines, it is necessary to analyze their work process.

As research assumptions, let's limit ourselves to the definition of working efforts on the working bodies of construction machines and equipment.

Analysis, which is a procedure for reducing complex concepts or ideas about an object to more widely known and simple ones, allows you to move from an undivided object to identifying its properties, signs, their relationships, structure and connections [2].

There are the following main types of analysis as a method of scientific thinking:

1) imaginary or real dismemberment of the whole into parts in order to identify the composition or structure of the whole and establish the relationships between the parts;

2) examination of a separate subject within a certain class of similar ones in order to identify the adequacy of their structure and transfer the knowledge obtained during the study of one subject to others;

3) differentiation of properties or relations between objects into constituent properties and relations for their description by more general simple concepts;

4) division of a set or certain classes of subjects into appropriate subclasses.

The main methodological requirements for the procedure for the implementation of various forms and types of analysis can be formulated as follows:

1) dismemberment of the researched objects into consolidated classes of elements (subjects, structures, connections, properties, relations, etc.) is done in accordance with their main essential feature or a set of such features;

2) dismemberment of classes of elements into their respective subclasses is carried out to such a degree that the obtained new elements retain the characteristic that defines them;

3) the distribution of elements by classes and subclasses subordinate to them is done according to the degree of their significance or influence on the functioning of the object being studied.

In mechanical engineering, the main task in the improvement of technology is the synthesis of construction machines, which takes into account the relationship between the physical and mechanical properties of the developed environment and the laws of motion of executive elements established during the analysis of the machine.

The effectiveness of synthesis in mechanical engineering consists in the imaginary unification of parts of an object, dismembered in the process of analysis, which allows establishing interactions, connections and laws of development of parts of the object to study it as a single whole.

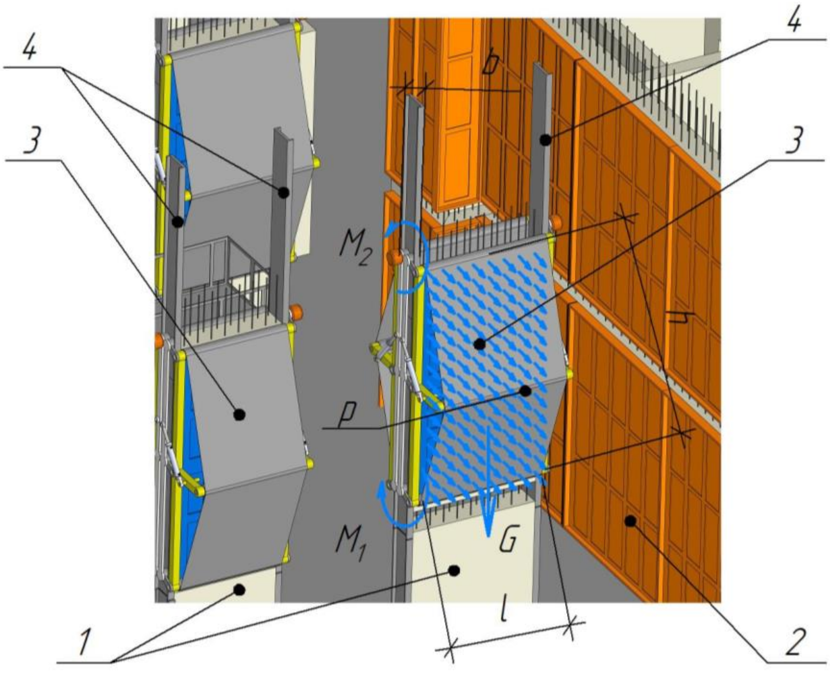


Fig. 1. Example of determination of forces for mobile formwork:
1 – building pylon; 2 – fixed formwork; 3 – mobile formwork; 4 movement guides of the movable formwork; l – pylon width; *h* is the height of the movable formwork; *b* – pylon thickness; *G* is the weight of the movable formwork; M_1 – the moment of resistance to the movement of the movable formwork; M_2 – driving moment of the movable formwork; *p* is the pressure from the concrete mixture in the concreting circuit.

At the same time, the nature of the change in internal forces in the machine elements that occurs during work is determined.

MATERIALS AND METHODS

To carry out research, we will analyze the power drives of heavy construction equipment and moving parts of mechanized technological equipment, in particular, moving formwork systems.

Research methods – literature research, visual modeling, simulation of working movements of executive items of construction machines and mechanized technological equipment.

So, the construction machine and the mechanized technological equipment work in specific stable conditions. In the event of a change in the area of application of the machine or equipment, the workload, the nature and law of movement of the executive body, and the amount of internal loads change (Fig. 1).

To study the patterns of load formation, we will consider construction machines with working bodies of the destructive type.

Various power drives are used in modern construction machines.

As can be seen from fig. 2 [3] power drives of construction machines by type of energy carrier include the main groups, such as: electric, pneumatic, hydraulic, diesel, explosive and various combinations thereof.

Power drives are the heart of any construction machine, providing it with movement, lifting loads and performing other necessary operations. The choice of drive type depends on many factors, such as the purpose of the machine, the required power, operating conditions, etc.

Power drives of construction machines can be classified according to various characteristics. The most common classification (fig. 2) by type of energy used:

Electric drives:
- **Advantages:** high efficiency, easy speed adjustment, wide power range.
- **Disadvantages:** dependence on the power source, the possibility of overheating of engines.
- **Application:** power tools, concrete mixers, cranes of small and medium capacity.

Internal combustion:
- **Advantages:** autonomy, high power.
- **Disadvantages:** harmful emissions, high noise level, complexity of maintenance.
- **Application:** excavators, bulldozers, truck cranes, asphalt pavers.

Hydraulic drives:
- **Advantages:** smooth adjustment of speed and force, high power in small dimensions, the possibility of transmitting large forces over long distances.
- **Disadvantages:** high cost, the need to use a special liquid, the complexity of the design.
- **Application:** excavators, cranes, presses, drilling rigs.

Pneumatic drives:
- **Advantages:** simplicity of design, high speed of action, possibility of use in explosive environments.
- **Disadvantages:** low efficiency, limited range of speed regulation.
- **Application:** hammers, pneumatic tools, control systems.

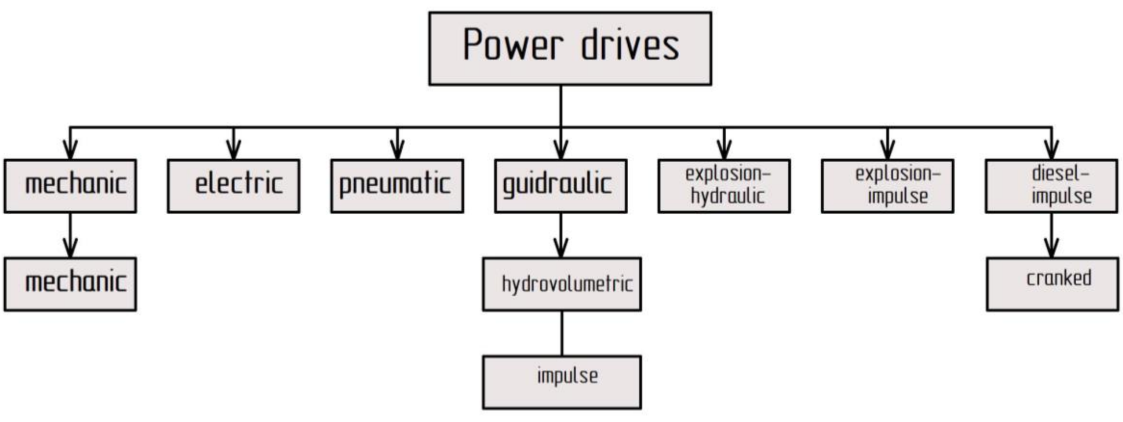


Fig. 2. Classification of power drives in construction machinery

Additional classification criteria

In addition to the type of energy, power drives of construction machines can be classified according to other characteristics:

- **According to the method of transmission of movement:** mechanical, hydraulic, pneumatic, electric.
- **By the number of degrees of freedom:** one-, two- and multi-degree.
- **According to the method of adjustment:** stepless, step.

The specificity of the use of each type of drive is the requirements for a specific type of working items.

The energy of operation of explosive-gas-hydraulic, explosive-gas-impulse and diesel-impulse drives is mainly generated from the combustion of a combustible mixture.

Electric drives are characterized by such temperature and power parameters that in most cases limit their use in high-frequency dynamic load systems.

Different from electric drives are mechanical drives (fig. 3) , which operate at high power and maintain a constant temperature regime. In diesel impulse drives, the dynamics are realized, as a rule, thanks to the crank converting devices. In this case, the energy is generated from the combustion of diesel fuel and is transferred to the mechanical energy accumulator - the flywheel, from which it is sent to the piston through the crankshaft and connecting rod, providing it with impulse translational movements.

The calculation of the required dynamic force is carried out taking into account the moment M on the engine shaft and the diameter D of the flywheel.

Significant disadvantages of the diesel impulse drive are its limited functionality and high environmental pollution. The working cycle of such a drive is ¼ of a full cycle, which is unacceptable for practical use due to a significant increase in reaction time.

Due to the implementation of any movements and precise positioning, the most acceptable actuators are pneumatic and hydraulic.

Pneumatic actuators can realize any specified movements of the output link with high accuracy, at sufficiently high actuation speeds (Fig. 4).

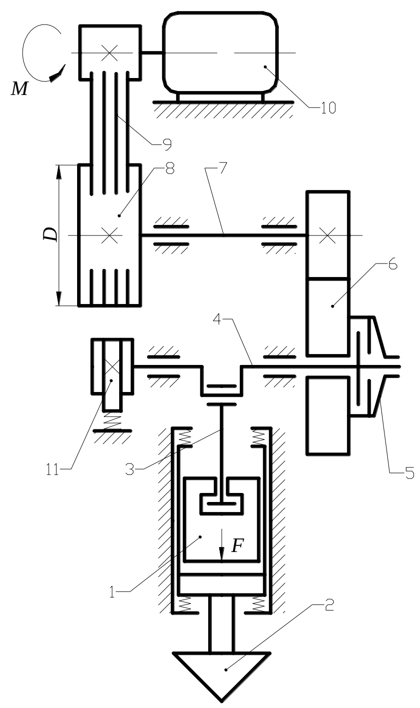


Fig. 3. Crank drive: 1- output drive link; 2- working body; 3- connecting rod; 4- crankshaft; 5- coupling; 6- gear transmission; 7- shaft; 8- flywheel; 9- V-belt transmission; 10- engine; 11- brake

But compared to hydraulic drives, they have a number of important disadvantages. Namely, hydraulic drives realize greater power, their environmental friendliness is achieved by the closedness of the system, and the properties of the working fluids on which hydraulic drives work allow reducing the overall dimensions of the drive elements to obtain a higher operating frequency of pulses at the output.

Hydro-inertial drives are systems in which the compression energy of the hydraulic fluid and the inertial properties of the mechanical parts of the system are used for dynamic loading. At the same time, the output pulsation is provided by the pulsator valve, which opens or closes the pressure channel from the hydraulic accumulator.

Systems with such drives are able to implement forces from 1 kN and a frequency of oscillations of 5 Hz from a drive motor with a power of 4.5 kW.

The main disadvantages of using systems of this type are that such a system is characterized by high inertial masses and significant dimensions.

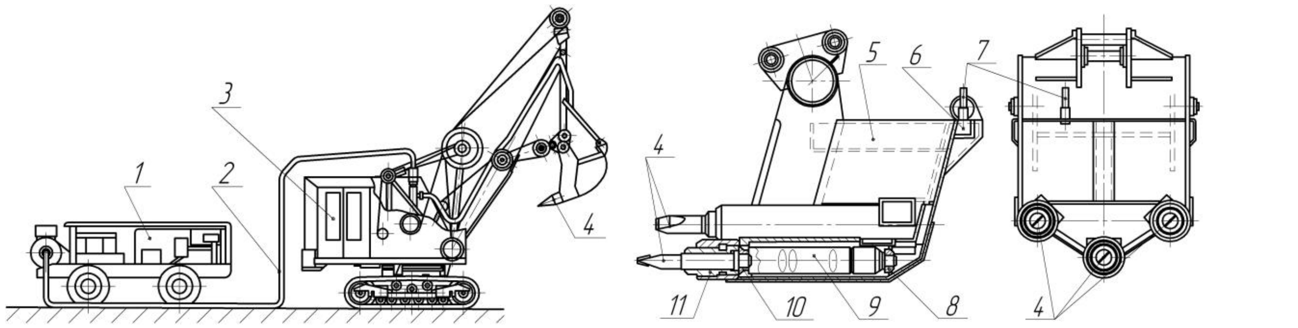


Fig. 4. Simle of using pneumatic drive:
1 – power station; 2 – power line; 3 – constriction machine; 4 – working item; 5 - excavator bucket body; 6 – power socket; 7 – power line; 8 – power socket; 9 – hammer drive; 10 – hammer; 11 – bush

1. In addition, the design of the system with a hydraulic impulse drive has a number of disadvantages:
2. The presence of a battery determines an additional cycle for charging it.
3. The pulsator valve is difficult to adjust, with a small diameter of the pusher.
4. When increasing the hole in the pusher to increase the speed of return of the spool to the initial position, there is a danger of the valve malfunctioning due to insufficient pressure drop to open the valve.

Different from the hydroinertial impulse drive is the batteryless impulse hydraulic drive with a crane-type pulsator (Fig. 5) [4]. In this drive, the pulse energy is generated by the liquid due to the alternate overlapping of the input and output holes in the valve-type distributor, and the battery is excluded from the hydraulic drive system, which determines the better sensitivity of the drive and its higher speed.

The advantage of such a solution is that during operation it is possible to adjust the frequency of oscillations by adjusting the speed of rotation of the drive motor of the distributor.

But a significant drawback remains that the crane-type distributor has a positive overlap, which at high overlap speeds and high pressures contributes to the formation of cavitation in the pipelines.

Taking into account the above provisions, a decision was made to develop a new batteryless dynamic drive. Moreover, in order for such a hydraulic drive to have a high speed, it is necessary to exclude the hydraulic accumulator from its scheme, as well as to design the pulsator in such a way as to avoid cavitation and expand the possibilities of regulating the pulsation frequency and pulse energy. In fig. 6 shows a throttle spreader that functions as an oscillation generator [4] . The difference in its construction is that the spool does not have flow channels for the working fluid (such as faucet spreader) , but is installed with an eccentricity e with the possibility of rotation. The overlap of the passage section f occurs smoothly through the angle $\pi/2$, which allows you to obtain two states of overlap in one revolution of the spool. During the period from the fully open cross-section f_{max} to the conditionally closed cross-section f_{min}, thanks to the installation of a non-return valve in the general scheme, the working fluid accumulates energy, which, upon the next opening of the cross-section f by the spreader, allows obtaining a pressure pulse in the system and, as a result, a load pulse on the working item.

A feature of this type of throttle spreader is that its spool provides negative overlap. At the same time, the condition of uninterrupted flow is fulfilled - the cavitation-free operating mode of the hydraulic system is ensured; it is possible to change the value of the minimum overlap in accordance with the operating conditions by changing the value of e .

The proposed design of the cylindrical spool determines the smooth law of change of the passage cross-section of the pressure pipeline depending on the rotation frequency. With the known law of change $d_y = f(\omega, R_1, R_2, e)$, it is possible to obtain the spool profile using the

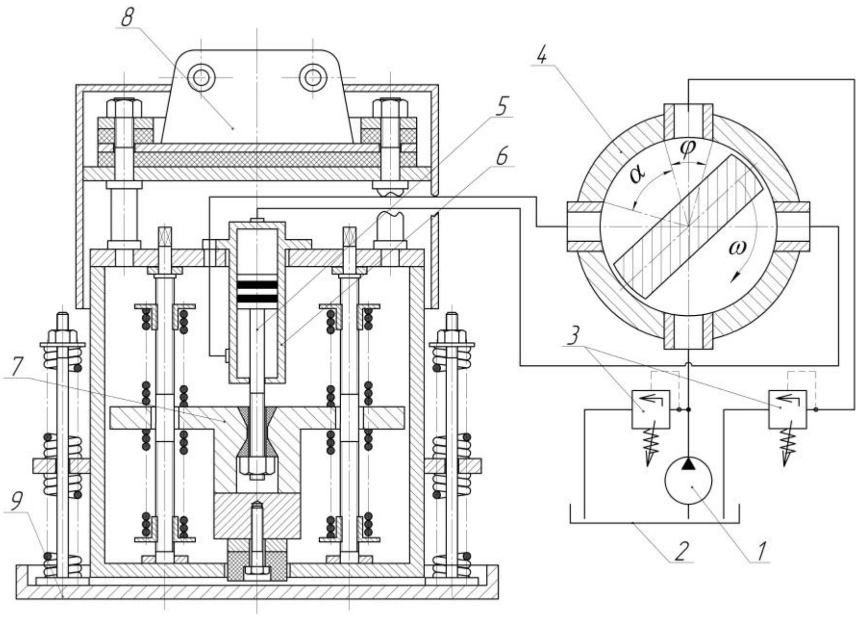


Fig. 5. Non-Battery dynamic hydraulic drive with a crane-type spreader:
1 - housing; 2 - vibration damper; 3 - inertial mass; 4 - drummer; 5- buffer; 6 - sealing plate; 7- hydraulic cylinder; 8- hydraulic distributor; 9, 10, 11, 12 - elastic elements; 13 - hinge; 14- rod; 15- tank; 16 - pump; 17, 19, 20, 21 - inlet holes; 18- spool; 22, 23 - overflow valves

method of synthesis of cam mechanisms [MM theory].

The proposed schematic implementation of the hydraulic impulse drive of the end working item of the construction machine or mechanized equipment with controlled power parameters allows to generate an impulse moment of up to 0.8 N·m·s on the power hydraulic motor, at a rotation speed of up to 100 s^{-1}, working pressure of 14 MPa, flow rate of the working fluid 150...300 l/min. The peculiarity of the scheme is that the oscillation frequency is controlled independently of the power drive, and its value can vary within 1...50 Hz.

On Figure 7 shows the scheme of mechanized modules lifting during monolithic concreting.

Concreting of pylons 1 takes place thanks to the use of formwork mobile module 2 [7] . Inside the pylons, reinforcement 3 is made. The work is carried out from a mobile support 4.

The central part of the building is concreted using a conventional shield formwork 5, on which the support 6 is placed.

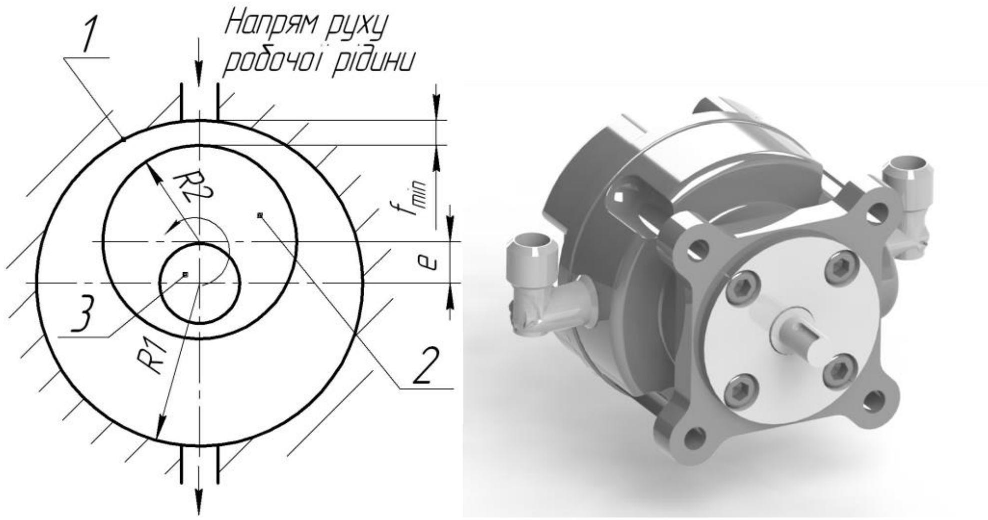
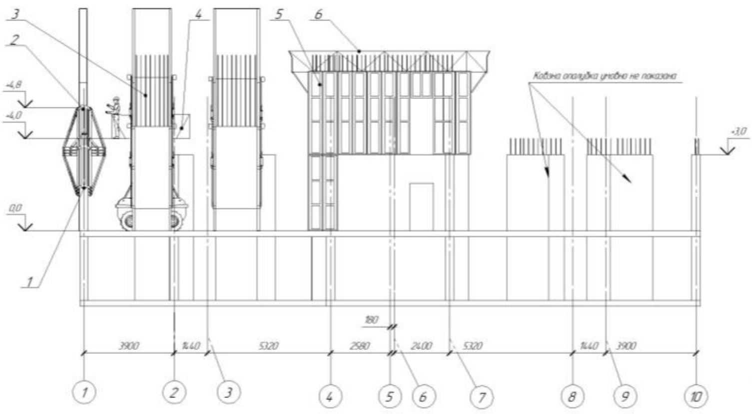


Fig. 6. Hydraulic oscillation generator:
1 – pulsator working chamber; 2 – spool; 3 – spool drive shaft

The sequence of work of formwork mobile module 2 is as follows. The concreting height per cycle is divided into tiers depending on the height of the formwork module. Formwork module 2 is set at a height of 0.0 so that the concreting contour is inside the formwork



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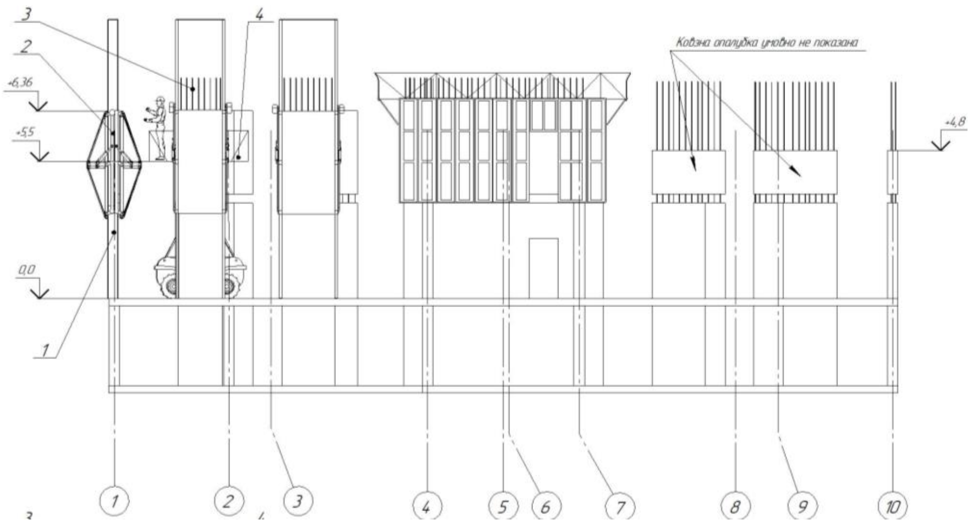

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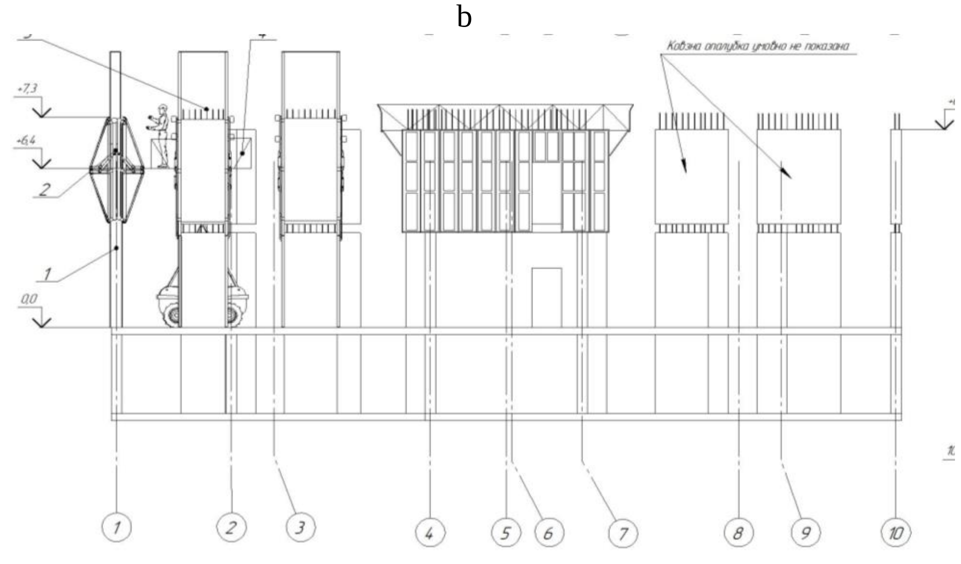

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Fig. 7 . Scheme of mechanized modules lifting during monolithic concreting:
1 – pilon; 2 – mechanized module; 3 – reinforcement; 4 - moving platform; 5 - panel (static) formwork; 6 - static platform

module. Next, concreting of the 1st tier is carried out to a height of 1/3 of the height of the formwork module. After a technological pause, concreting of the next tier is carried out. When the concrete gains the necessary strength, the formwork module is moved vertically upwards, to the height of the tier. The operations are repeated until the required height of pylon 1 is reached.

It is technologically important to ensure the vertical movement of the moving module by the drive of the module itself. At the same time, it is necessary to take into account the force of adhesion of the moving module tape to the concrete, take into account the need for smooth movement to avoid tearing off pieces of concrete from the structure, the need to brake or fix the moving module in space relative to the concreting structure.

At the stage of formation of the movement drive scheme of the movable formwork module, important indicators are:

- geometric parameters of concreting: width and height of concreting, thickness of the pylon;
- cyclic movement, determined by the physical and mechanical properties of the concreting mixture;
- geometric parameters of the drive and tension rollers of the movable formwork module: the diameter of the roller, which affects the force of tearing off the tape of the formwork module from the concreting contour during movement;
- the presence or absence of guides of the movable formwork contour, which determines the design features of the drive of the driving part of the formwork module.

The drive of the mobile formwork module must perform the following functions:

- **Energy Conversion:** Convert electrical, hydraulic, or pneumatic energy into mechanical work to move or fix a process module
- **Regulation of speed and force:** Provide smooth regulation of the speed and force of movement of the formwork module, which allows to adapt the equipment to different working conditions.
- **Ensuring accuracy:** Provide high accuracy of positioning of the formwork module.
- **Safety Assurance:** Protect people and equipment from damage with built-in safety systems.

Modern trends in the formation of construction equipment drives are associated with the use of new materials, electronics and software. This makes it possible to create more compact, powerful and energy-efficient drives with a high level of automation.

In the future, we can expect further development of construction equipment drives in the following directions:

- **Development of electric drives:** Due to their efficiency and ease of control, electric drives are becoming more and more popular.
- **Development of automatic control systems:** Automation allows to increase productivity and accuracy of construction processes.
- **Use of intelligent systems:** Intelligent systems allow you to adapt the operation of the drive to changing environmental conditions.

CONCLUSIONS

Formation of the composition of drives and determination of the workload during the mechanization of construction processes of equipment is a complex process that requires a deep understanding of the principles of operation of mechanisms, electronics and software. Modern trends indicate that drives are becoming more intelligent and efficient, which opens up new opportunities for the development of the construction industry.

Separately, it is necessary to determine the possible directions of further research:

- Research of new materials for the manufacture of actuators to reduce the weight of technological equipment.
- Development of new ergonomic drive management algorithms of movable technological equipment.
- Creation of intelligent drive monitoring and diagnostics systems.

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Аналіз принципів формування робочого навантаження в силових приводах будівельної техніки та оснащення

Алла Єсипенко[1], *Володимир Рашківський*[2], *Юрій Заєць*[3]

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

Анотація. Метою пропонованої статті є аналіз засад формування робочого навантаження на виконавчі органи будівельних машин і технологічного обладнання, що зумовлено необхідністю їх удосконалення з метою підвищення енергетичних і технологічних показників технологічних процесів. .Методика базується на пошуковому, дослідницькому та творчому підходах. Використовувалися методи аналізу розробки, патентного пошуку, синтезу технічних рішень, імітаційного моделювання. **Наукова новизна.** Дослідження різних підходів до забезпечення реалізації робочих рухів виконавчих органів будівельних машин і механізованого технологічного обладнання, аналіз технічних рішень дозволили обґрунтувати напрямки розвитку приводів будівельних машин для забезпечення необхідних закономірностей руху виконавчих елементів. Авторами запропоновано конструктивні рішення синтетичних приводів будівельних машин і обладнання, запропоновано енергозберігаючі підходи, спрямовані на зниження енергоспоживання. **Результати досліджень.** У статті розглядаються важливі питання аналізу формування навантажень на виконавчі органи будівельних машин і обладнання. Представлено синтезовані конструктивні рішення, отримані в ході патентних досліджень, аналізу сучасних технічних рішень, раціонального технічного проектування та експертної оцінки. Запропоновано технічне рішення, що забезпечує реалізацію адаптивної подачі в гідроприводі, яке може бути використано при модернізації існуючих приводів будівельних машин і рухомих частин механізованого технологічного обладнання.

Ключові слова: навантаження, механізоване технологічне оснащення, будівельна техніка, продуктивність, оптимізація**.**