DOI 10.52209/2706-977X_2025_2_22 **IRSTI 55.30.29** **UDC 622.272**

Structural and Parameter Analysis and Study of Mechanized Supports for Their Robotization

Zhetessova G.S., Beisembayev K.M.*, Abdugaliyeva G.B., Orazbekov D.E., Levshanov R.V.
Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan
*corresponding author

Abstract. Ensuring the wear resistance of the main components of mining machines and their long-term operation in an abnormal working environment of the subsurface, where elements are dynamically loaded with pressures exceeding 130 MPa, raises research challenges. Solutions to these challenges can be based on software packages with advanced intelligent functions and mechatronics, with the development of programs in the form of code for rapidly changing conditions. The study of the structure of support sections shows that the formation of loads on the basic elements, which are most susceptible to wear, is determined by the kinematics of the design, the types of connections at the joints, the accuracy of manufacturing, and assembly procedures. Structural formation through models of kinetostatics, circuit engineering, and mechatronics is a promising tool for obtaining efficient designs. They are easily converted into a control database of multidimensional classifications with processors at the database nodes that correspond to the software implementation of the structures, and their digital models include modes of operation in the working environment. For the KNC 70 support technology developed by the Coal Institute in Kemerovo, uneven loads in the joints of the rotating arms have been identified during roof displacement. This causes deviations in the loads of the control jacks from their axes and creates wear zones. The calculation takes into account the friction coefficients of the sliding parts. Such zones are particularly pronounced during the accelerated movement of the piston while transporting massive structures. Data on their distribution allows for the identification of solutions to reduce this effect. A method has been developed for the computer-based accounting of the interaction of cantilevered canopies, controlled by a jack, with the rough surfaces of rock to determine the distribution of load along their interaction line. The selection of control systems is based on applications that provide results in the form of data and text-based programs in the languages that form the foundation of robotic control systems, which will allow for the safe use of artificial intelligence, which is controlled by the operator through easy-to-read and understand commands.

Keywords: unevenness; structure formation; wear; digital model; interaction lines; Artificial Intelligence

Introduction

Modern longwall mining technologies are based on the use of a wide range of bulky and expensive equipment. Therefore, significant capital investments are required to create a new section in the mine. However, earlier experience has been presented in the application of technologies with much lower capital intensity. These are chamber technologies. They are successfully applied for the extraction of complexly deposited minerals in the USA, India, Australia, and Russia. The work zone in chamber technology is such that it can be easily isolated from other sections, and therefore harmful gases do not enter the atmosphere.

The efficiency of chamber technologies is particularly high in the extraction of potash salts in Russia, which brings significant income to the country. This has been achieved by mining chambers with the efficient Ural 20 KS type combine harvester, which was developed with the involvement of Karaganda engineers. Currently, manufacturing enterprises in Kazakhstan do not produce such combines, and mainly imported mechanized complexes are used in the mines. The problem of restoring such plants or separate workshops is compounded by the fact that Kazakhstan is still focused on creating assembly plants that generate quick income, such as the assembly of cars and components based on rubber technical products. At the same time, it has been characteristic for the engineering enterprises in the region to manufacture mechanized supports of a new technical level, where the processing of their hydraulic equipment (movement jacks, lateral leveling jacks, supports) was carried out using numerical control machines and software for processing rods and cylinders with a radius of 0.025 to 0.3 m for operation under pressure up to 360 MPa.

The Karaganda complex M-130 demonstrated effective operation even in panels no longer than 120 meters, achieving a daily extraction of 3000 to 4000 tons. The use of the OKP-70 support made it possible to achieve a record monthly extraction that still stands today [1], [2]. The operational efficiency and longevity of machines depend on the quality of their component manufacturing and the kinematic design of the machine, which should reduce dynamics and ensure minimal reaction forces in hinged connections. This will determine the necessary wear resistance, especially of surface components that move relative to each other. This applies to the canopy of the support that moves along the roof, the rod and piston in the cylinder, and the cylindrical pins in the eyes as well as the spherical supports of the posts [4] – [6].

The aim of the work is to analyze and study the structure formation of sections of mechanized supports for their transformation into a robotic complex for chamber mining of complex coal seams, using methods of linearization of dynamic equations to simulate three-dimensional maneuvering of sections, including asymmetric loads from rock pressure.

1. Methods and experiment

Structural analysis, as a research tool, improves as it is applied. Along with its use for established technologies, it also serves as a means for creating and introducing innovations in mechanics, as well as in the processes of changing the structure of machines and manufacturing materials. This is carried out in software packages that produce results in the form of data and program models expressed in text code, which can be easily modified in editors and used in other packages, allowing for the construction of a well-founded digital model of the machine, as shown in Figure 1. For the analysis of structural diagrams, Figure 2 utilizes the technology of linearizing dynamic equations (LDE), which offers a relatively simple representation of motion based on kinetostatics. This allows, based on 3D models, to obtain comprehensive information about the design and kinematic capabilities of the section, the structure of its hinge system and interaction with other machines in the unit.

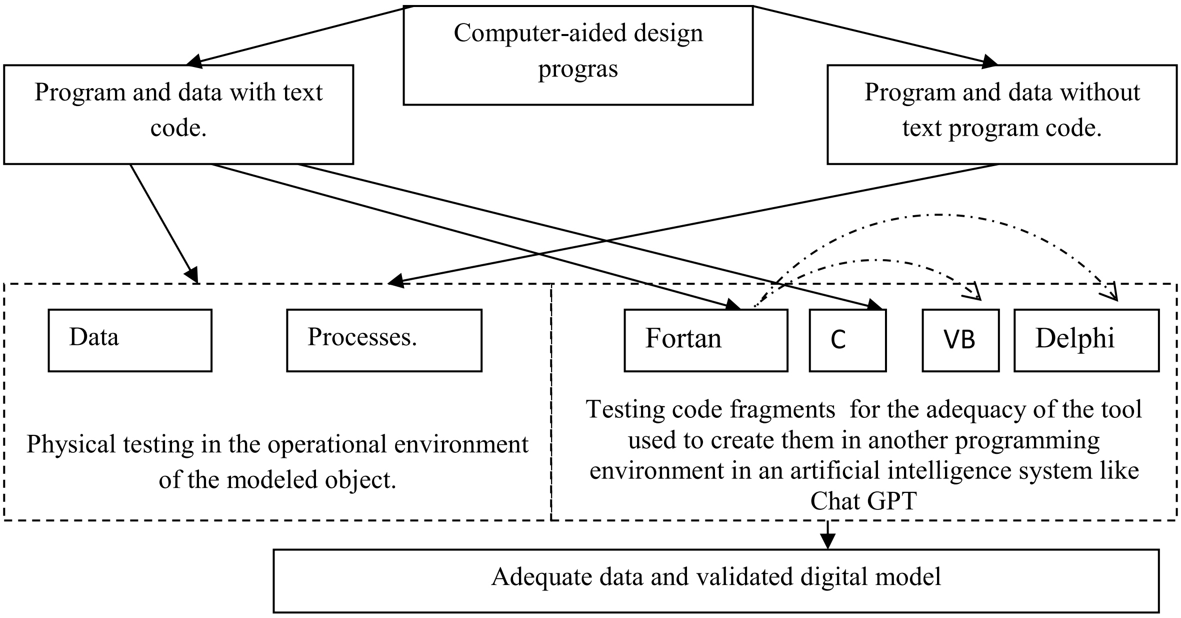


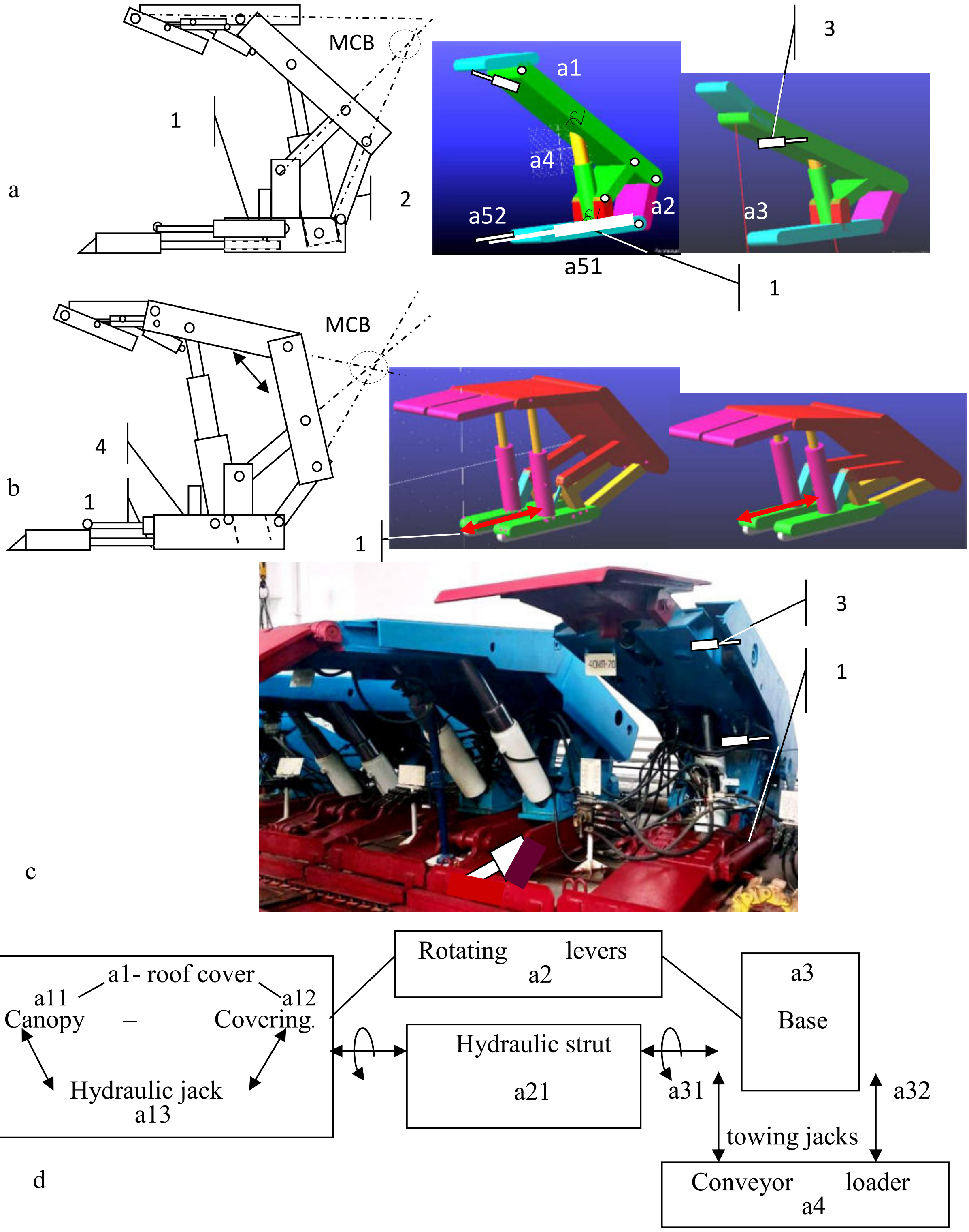
Fig. 1.- Algorithm for testing the product developed using artificial intelligence design software packages.

As the conducted experiments show, for the analysis of the machine structure, the proposed method for creating a kinematic-static model is the most acceptable due to the use of standard elements. In this case, the structure of the machine is simplified, but all dynamic characteristics are performed with sufficient accuracy, which can be easily established by the displacement speed of real samples and the model. There is no need to execute a complete constructive implementation of the model; it is enough to consider the masses and axial moments of inertia of the parts, using two primitives (Linck, Box) and three constraints (Revolute, Zulindrical, Translate).

Please note that packages for working with mechanized supports and their robotic systems contain functions and structures oriented towards the finite element method, therefore text programs created in these packages (for example, Ansys APDL) should be verified in Fortran-type languages, and individual fragments of them (without FEM functions) should be verified in VB or Delphi languages, which are usually available to a large contingent of users. At the same time, to improve the program (usually these are lines for determining the current state of the face when moving support sections), which you offer to execute AI, you should specify operator options that are well known to you, which will significantly reduce the number of errors in the resulting code.

The proposed schemes and programs represent dangerous operating modes, and, in particular, for the lemniscate mechanism, where the intersection of its instantaneous center of rotation (ICR) with the axial lines of the visor or the overlap causes an increase in the loads in the hinges of the four-link levers.The control program should consider preventing such positions. The diagram was created based on a textual description of the structure. Using circuit engineering, it fully represents the design and kinematics of the section, including its connection with the loader-conveyor. Diagrams a to b primarily express a research variant of the structure and do not significantly lag behind photographs of the real design due to their mobility. Diagram c, despite the main textual description, fully represents the data and processes. Moreover, it allows the construction description to be integrated into traditional databases with special indexing of design elements. Previously, we presented the structure of a multidimensional database for the sections of the support [2] in the form of a window for an infological model, the content of which is enhanced by the introduction of models of type a and b.

The data base contains references to modeling packages in its nodes, and for this reason, the diagrams of types "a" and "b" represent the capabilities for dynamic description of loading and displacement of the section. The database for the sections is structured such that the main element of its design is the support, as it provides the primary function for the safety of personnel during operation.



a – shield (protective-supporting) section of the support; b – supporting-protective support; c - Section of the OKP-70 support in the machine room of the KarTU, on the left Glinic: 1 - travel jack (a51, a52), 2 - rotary levers of the lemniscate mechanism (a2), 3 - side jacks, 4 - conveyor control jack.

Fig. 2.- Structuring of support sections to form a robotic system

Currently, two types of constructive implementations of sections are mainly used (see Fig. 2), which we categorize as: protective-supporting and supporting-protective.

In the figure, using schematic techniques, the structures and connections of support sections are presented, highlighting their potential for automation when working in the challenging conditions of mines and quarries. Mechanized support operates under pressures that no other machine experiences. This is due to the vast height of the rock column (up to 700 meters) acting on the section, creating hanging rock in the mined space that periodically collapses onto the moving support with spans of 20-25 meters. The pressure in the supports can reach values of 25 to 130 MPa. Moreover, the optimal technology for working with it should minimize, but ensure, the presence of a person in the mining face. The weight of a section can reach 12 tons, and having 150 to 200 sections in a face requires significant capital investment and operational costs.

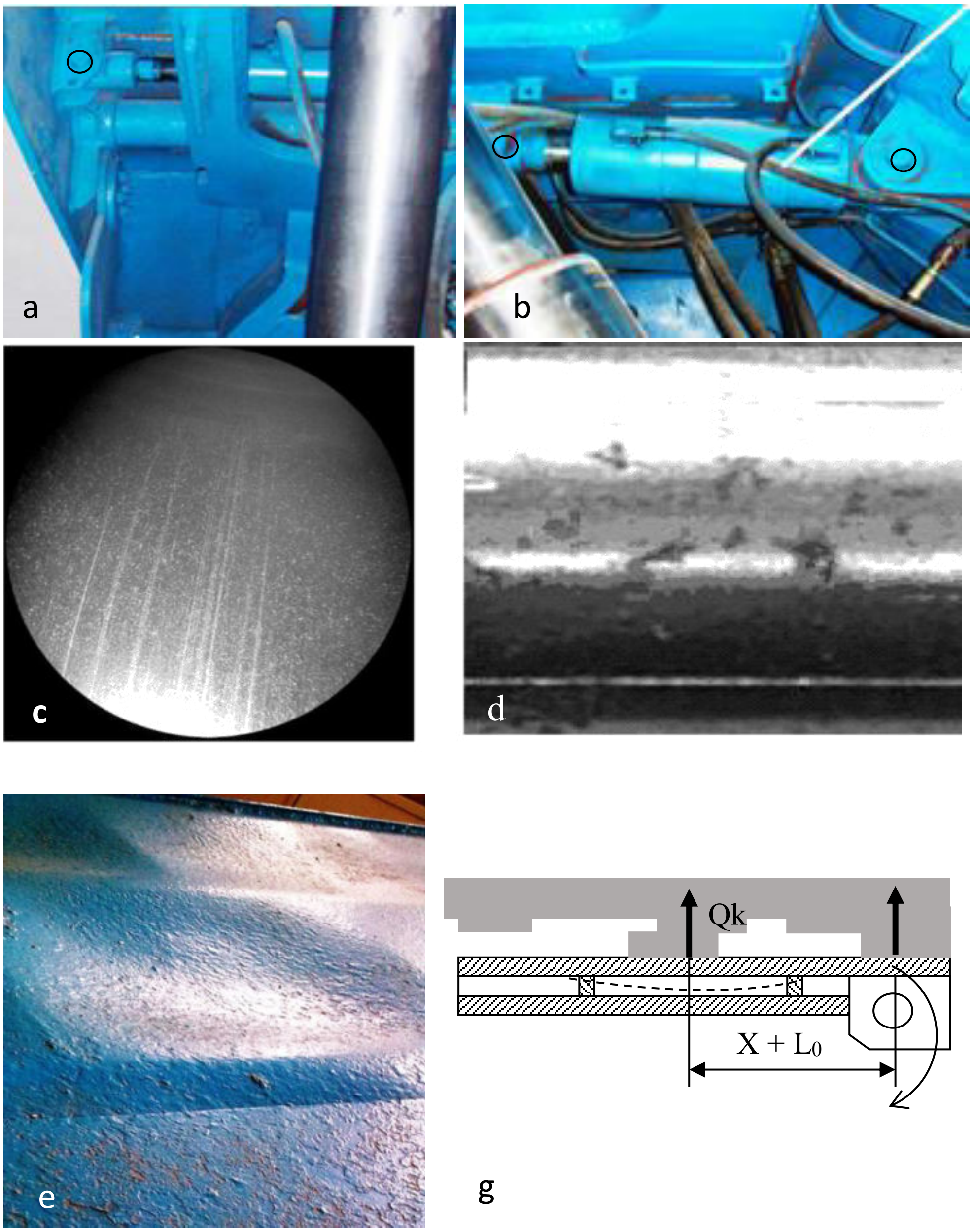
The complex of these factors necessitates for the enterprise to recover the cost of the equipment through continuous operation, which is possible only under ideal mining and geological conditions. At the same time, support sections of the OKP 70 type have been operating in the Karaganda basin for over 40 years. Its design, featuring a powerful support embedded in the rear part of the section, provides ample space for worker passage and ventilation in the face, given the super-category gas factors of the Karaganda coal seams, as shown in Figure 2.

The proposed representation of the structure and kinematics for sections of both types, unlike the photographs of such sections, as shown in Figure 2c, allows for modifications and improvements to the design, enabling the synthesis of their force parameters. This has been made possible through their creation in LUD packages, under simplified kinetostatics, in conjunction with established standard means of visualization that are easily separable from the computational part, which is important for effective testing.

2. Results and discussion

Assistance in creating such tools is provided by artificial intelligence (AI) packages, specifically: DQN (Deep Q-Network) - for feedback-based learning, PPO (Proximal Policy Optimization) - for reinforcement learning in complex environments; CNN (Convolutional Neural Networks) - for processing visual data. They also address issues related to robotics. However, effective dynamic analysis is still carried out using packages such as MATLAB/Simulink - tools for modeling and analyzing dynamic systems; ADAMS (MSC Software) - specialized software for the dynamic analysis of mechanical systems and mechanisms with robotics processors; and the SolidWorks Motion module, for the dynamic analysis of moving mechanisms. In recent years, the interviewing of AI systems has been developing, which, when questions are structured correctly, allows for the identification of the best systems, as well as, by analyzing the responses, uncovering fundamental flaws in AI, including instances of obtaining inadequate information. The developers of these systems do not impose restrictions on their use in a resident mode, and in a paid mode, they are still inexpensive, thus providing opportunities for support in programming. The effectiveness of AI in design has already been proven, but even now, there are known cases of obtaining unreliable data. Therefore, the creation and expansion of testing methodologies is the best way to address such situations, and it is greatly simplified when there is a result not only in data but also in the form of source code that corresponds to the capabilities of interpreters of popular object-oriented languages such as Fortran, C++, Delphi, and VB.

Therefore, the use of CAE packages, such as ADAMS (MSC Software) or Ansys APDL, where the testing technologies from Figure 1 can be easily applied, will allow for a safer transition to and expansion of the use of AI. Thus, the necessity to verify the obtained results through alternative means is an important point for accelerating development. This is where the continuity of technologies and their tools comes into play. We note that the use of packages that do not generate text code is quite justified in well-studied areas of engineering and processes based on proven kinematic schemes, designs, materials used, and levels of their loading. Clarity of the structural scheme is especially important in the processes of interaction between the machine and the working environment, and in the presented example with roofing, accounting for its roughness will allow for a more accurate synthesis of its parameters. As can be seen from the diagram in Figure 1, a single section of the support can contain up to 8 hydraulic cylinders, and servicing them in automatic mode will require 24 sensors (16 pressure sensors and 8 position sensors). Therefore, the application of mechatronic solutions is an important aspect of structural analysis. In this case, the sections in Figure 2 have up to 11 main nodes, considering the supports and the jacks controlling them, as well as over 20 articulated systems for their connections. The sections of OKP 70 can rotate left and right by 180 degrees within these systems, with the turning radius being such that, for the structure described in the Eurasian patent application by the authors N 202391679, it does not result in losses of useful minerals. They can also move upward and downward along an inclined surface of no less than 25 degrees. The presented system allows for the simulation of these movements, conducting process and parametric analysis, and calculating the duration of their execution [5]. The hydraulic cylinders have easily vulnerable parts - namely, the rods and cylinders - that require special precision treatment for smooth operation. Wear on these components leads to leakage of working fluid and equipment failures. Suboptimal connections between the units of the support section can exacerbate wear. Thus, Figure 3a, b, c, d examines the causes of wear related to the joints of hydraulic cylinders with other components of the support section. Wear at the lugs causes load misalignment from the rod axis, for instance, in the movement jacks located at the base of the section. Rock and coal debris accumulates in the inter-sectional gaps, entering the lugs, which leads to wear and deformation of their openings. Dynamic analysis of the movement of the piston and rod in the hydraulic cylinder shows that, in this case, the wear zones in the sliding systems are intensified and can concentrate in areas of stress concentration, such as those located at the Grund-bushing—the zone of the rod's exit from the cylinder during accelerated rod movement, as shown in Figure 4. The relevance of such issues is highlighted by data [4], which indicates that failure rates of support columns in longwall faces reached 31%, and for jacks, 23%. The reasons include impacts during the collapse of roof blocks (37%) and loss of longitudinal stability (28%). Load misalignment on one of the jack lugs also causes bending moments on the rod. Such situations are common in longwall operations due to sharp irregularities in mining pressure.



a, b - mounting of hydraulic cylinders with the possibility of non-axial loading; c, d - wear of the rod in the presence of bending moments and corrosive factors; e - scheme of random interaction and deformation of supporting elements for the real rock environment

Fig. 3 - Irrational mounting of hydraulic cylinders and selection of the calculation scheme.

Thus, structural models of types a and b, when using the LUD processor, allow for the simulation of unilateral rock displacement, which leads to tilting of the support section and uneven loads on the lugs. For this situation, a model of the support section has been developed for coal release from the upper coal seam onto the face conveyor, designed by the Coal Institute of the Russian Academy of Sciences (Kemerovo), as shown in Figure 4c, with a bearing capacity of support columns up to 900,000 Pa.The graphs depict a case where the load was concentrated on one side of the canopy, leading to a sharp redistribution of reaction force magnitudes at the joints to the left and right of the section, causing it to tilt laterally. In this case, the movement of the side edges of the section using type 4 jacks, as shown in Figures 2a and 2d, will result in non-axial loading on the jacks, as illustrated in Figure 3b. However, for a support that has spherical joints, this situation is not dangerous.

However, for a support that has spherical joints, this situation is not dangerous. The most heavily loaded areas of the sections are their supporting parts: canopies and bases. The issue of crushing sheets between the supporting ribs has been successfully addressed by thickening the outer sheets in contact with the rock, as shown in Figures 2e and 2g. As a result, the durability of the metal structure has significantly increased (for example, the supports of OKP 70 have been in operation for over 40 years!). The kinematics of the section, as the analysis showed, will provide operational modes compatible with those of the robots [5], [6], and it is sufficient to replace hydraulic equipment with electro-hydraulic equipment, for instance, based on systems from the Marco company (KarTU has a memorandum for joint work). The wear of the surfaces of the coverings, canopies, and bases should be considered proportional to the distribution of average loads along their contact lines with the rock.

In addition to the deformation of the crushed surface of the canopy and the cover, the sliding of rock blocks on them is also taken into account, causing, due to friction, additional abrasive wear..

When analyzing the interaction of the covering with the rock, the influence of the cantilevered canopy, operated by the jack, is also taken into account. The canopy, pivotally connected to the covering at point O, has a single support zone with the rock, and its position along the length of the canopy is considered uniformly probable. The first contact point is the hinge at point O; therefore, for the scheme shown in Figure 5, we have three contact zones. After the movement of the section and the bracing of the support, we have two contacts located on the covering on both sides of the resultant force. The determination of loads along the contact line for Figure 3g corresponds to simple equations of equilibrium.

$$Qi + Qj + Qk = \Sigma\ Pi; \quad Qilci - Qjlcj - Qklck = 0, \tag{1}$$

For a uniformly probable contact scheme, we obtain:

$$\text{Qjcp}=\frac{1}{(mk * m\text{л})} * \sum_{k=1}^{k=mk} \cdot\cdot \sum_{i=1}^{i=m\text{л}} \frac{\sum P(2i-1)(2k-1)l_{kk} - 4Mom_k(i+mn)}{2l_{kk}(i+j+k-1)(2k-1)}, \tag{2}$$

$$\text{Qicp}=\frac{1}{(mk * m\text{л})} * \sum_{k=1}^{k=mk} \cdot\cdot \sum_{j=1}^{j=m\text{л}} \frac{\sum P(2j-1)(2k-1)l_{kk} - 4Mom_k(i+mn)}{2l_{kk}(i+j+k-1)(2k-1)}, \tag{3}$$

$$\text{Qkcp}=\frac{2Mom_k}{l_{kk}(2k-1)}, \tag{4}$$

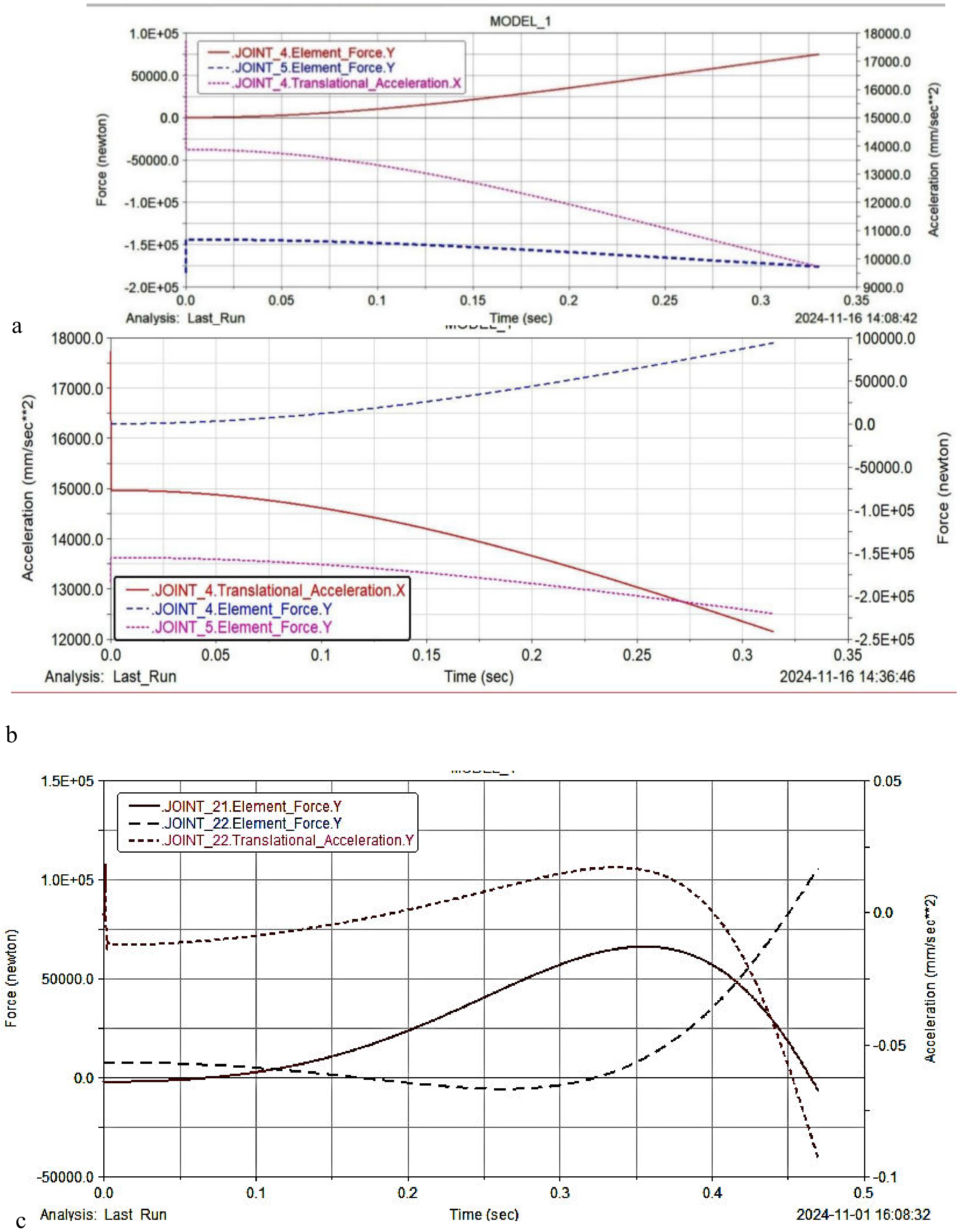
where lkk is the length of the cantilever awning.

From the condition of interaction under which the moment M will be minimal, ensuring contact across all sections, we obtain:

$$Mo = \frac{Pl_{kk}(2k-1)(2i-1)}{4m_k(i+m_n+k-1)}, \tag{5}$$

The calculation program takes into account the factor of increased interaction frequency at the edge of the eave. Adjustments to the distributions consideration is given to the influence of the equality:

$$\sum_{n=(Lk/A)}^{n=1} Pk(Lk/A-k)(Lk/A), \tag{6}$$



a - static and dynamic friction coefficients of 0.7 and 0.4; b - static and dynamic friction coefficients of 0.4 and 0.2; c - reactions in the pivot arms on the left and right under uneven loading of the section.

Fig. 4 - Normal reaction forces on the surfaces of the piston and in the area of the guide and bushings, as well as the load on the joints of the pivot arms for the volumetric model.

Where Pk is the coefficient of load non-uniformity along the contact line; Q is equal to the total resistance of the supports; Qi is the pressure to the left of xc; Qj is the pressure to the right of xc; Qk is the pressure on the roof from the eave side for the zone at the k-th section. The load distribution for such a ceiling is not entirely optimal. There are two peaks in the zone of the resultant supports and above the hinge of the eaves. At the same time, there is a noticeable reduction in loads on the rock between these zones, which, in the case of a roof model with cyclic cracks, could lead to the possibility of significant settling and the formation of rock blocks in this area [8]. It is also clear that the depth of this "pit" can be managed through active support using jacks on the eave. Based on the analysis, the use of eaves with a hinge in their middle part would be more effective for this scheme, as achieving a uniform load distribution in this case would be much easier. Taking into account the influence of the factor presented in expression (6) leads to an increase in the load at the end of the eave by almost 30%.

Thus, the structural approach to the analysis of mechanisms allows us to present effective technologies of chamber mining, which have a universal set of robotic equipment for the extraction of seams in difficult conditions, fundamentally different in terms of the factors complicating the work (fractures, changes in the angles of incidence of seams, steeply inclined and steep seams, the presence of weakened zones in the roof and soil), which also allows us to reduce the range of equipment and technologies of the type [11], [12], significantly simplify the volumes of necessary research due to the use of already tested equipment, assembled into new structures, and the use of programs based on modeling packages, the forecasting efficiency of which has been proven [13]-[16], and the adequacy of the work has been confirmed by Artificial Intelligence.

Conclusions

The analysis of the structures of the mechanisms can be conducted by creating simple models in dynamic programming packages based on kinetostatics. These models can easily be converted into a control database built on the principle of multidimensional classifications, with processors located in the nodes of the database, logically corresponding to their software content. The structures can then be expanded into complete digital models with device functionality in the working environment and applied in parametric analysis. This made it possible to identify wear zones in the piston rods and cylinders of hydraulic jacks, taking into account the friction coefficients of sliding parts during their accelerated movement during transportation of massive structures, as well as possible structural designs for the connections to reduce this effect.

Expressions have been obtained for the computer accounting of the interaction between the cantilevered jack-controlled canopy and the rough surface of the roof, for determining the load distribution along the interaction line, which allows for consideration of the zones of their intense wear. It has been established that the increase in load at the end of the cantilevered canopy reaches 30%, which must be taken into account during their fabrication, especially during the operation modes of the working areas with ceiling-reserved shapes, when the upper ledge is knocked down during the movement of the canopy. An important element of the automated design packages for robotic systems is the presence of tools that display the source code, which can be used in the logical blocks of automated execution of basic functions, as well as for testing the obtained results in an alternative programming language environment. This is particularly important when using packages where access to the internal workings of the solvers is restricted by the manufacturer, allowing for the safe use of artificial intelligence in design.

Structural analysis of the formation of design and kinematic schemes of sections of mechanized support is an important element of the analysis of their suitability for robotization. It has been established that the support section of the OKP 70 type complies with the principles of robotization when replacing its hydraulic system with electrohydraulic equipment with processors. At the same time, a step-by-step modernization of its metal structure should also be carried out.

References

[1] The head of the government congratulated the miners of JSC "Ispat-Karmet" on setting a world record for monthly coal production. //https://www.caravan.kz/news/glava-pravitelstva-pozdravil-shakhterov-oao-ispatkarmet-s-ustanovleniem-mirovogo-rekorda-mesyachnojj-dobychi-uglya-178208/. View date 21.11.2024

[2] Asmagambet D.K., Buyalich G.D., Zhettesova G.S., Beisembayev K.M., Akizhanova Zh.T Investigation of the rotary system for removing chambers //Ugol, № 6, 2023, pp.50-55.

[3] LI Dexing, Wang Enyuan, Yue Jianhua, et al. A weak current technique for coal and rock dynamic disaster prediction and its application.//Chinese Journal of Rock Mechanics and Engineering, 41(4), 2022. - p.764−774.

[4] Sinkov V.G., Nemtsev E.N., Miroshnichenko S.V., Khorolsky A.A. Increasing the load-bearing capacity of hydraulic props in mechanized supports //Geotechnical Mechanics 2015. №125

[5] Nikonova T.Yu., Zhetesova G.S.; Beisembaev K.M., Abdugalieva, G.B., Zharkevich, O.M., Skaskevich A. Chamber extraction of minerals in complex mining and geological conditions without carbon emissions // Ugol, № 11, 2024. - p. 57 – 63.

[6] Govorukhin Yu.M., Rib S.V. Modeling of detailed methods of proce ss coverage of the krovli river. // Gorny magazine, No. 4, 2019. - p. 23-26

[7] Yub B., Peng M., Tai Y. Assessment and control of the mine tremor disaster induced by the energy accumulation and dispersion of thick-hard roofs //International Journal of Mining Science and Technology, Volume 34, Issue 7, 2024. - p. 925-941

[8] Mena A., Wollstein R., Baus J., Yang J. Finite Element Modeling of the Human Wrist: A Review // Journal of Wrist Surgery, Vol. 12 No. 6, 2023. - p. 478 – 487. https://www.thieme-connect.com/products/ ejournals/pdf/10.1055/s-0043-1768930.pdf.

[9] Beysembayev K.M., Reshetnikova O.S., Nokina Z.N., Teliman, I.V., Asmagambet D.K. New technologies of mining stratal minerals and their computation //New technologies of mining stratal minerals and their computation //IOP Conference Series: Materials Science and Engineering 2018, 327(2), 022012

[10] Isabek T.K., Khuangan N., Altpayeva A.R., Shalmerdenova R.T. Modeling The Outburst State of an Arrau With Disjnctive disruption and Mining using the Finite Element Method //Ugol, № 6, 2020.- p. 55-60.
[11] Nevzorov D.N., Trufanova I.S. Improving the efficiency of a conveyor train: a study of the influence of drive station parameters on the adhesion force //Mining Industry. № 1, 2025. – p. 184–191
[12] Garashchenko Zh.M., Teremetskaya V.A., Gabov V.V. Mining of coal pillars with unified extraction modules and local faces //Mining industry, № 58, 2024. – p. 151–157
[13] Rojter M., Krah M., Kisling U., Veksler Ju.A. Razrabotka metoda sejsmoakusticheskogo monitoringa dinamicheskih javlenij v ochistnyh zabojah ugol'nyh shaht //FTPRPI, 1, 2021. – p. 28-35.
[14] Yu B., Mingxian Peng M., Tai Ya., Guo Sh. Assessment and control of the mine tremor disaster induced by the energy accumulation and dispersion of thick-hard roofs //International Journal of Mining Science and Technology, Vol.34, Issue 7, 2024.- p. 925-941
[15] Plykin M. Parallel Computing in Ansys. URL: //https://www. ansysadvantage.ru /parallel-estimates-in-ansys.(Date of access. 23/04/2025)
[16] Nabiullin R., Teliman I., Khoroshavin S. The interaction of the main actuators of hydraulic excavators //E3S Web of Conferences: 18, Ekaterinburg, 02–11 april 2020. – Ekaterinburg, 2020. – P. 03013. – DOI 10.1051/e3sconf/202017703013.

Information of the authors

Zhetessova Gulnara Santayevna, d.t.s., professor, Abylkas Saginov Karaganda Technical University
e-mail: zhetesova@mail.ru

Beissembayev Kakim Manapovich, d.t.s., docent, Abylkas Saginov Karaganda Technical University
e-mail: kakim08@mail.ru

Abdugaliyeva Gulnur Baimurzayevna, c.t.s, associate professor, Abylkas Saginov Karaganda Technical University
e-mail: gulnura84@mail.ru

Orazbekov Darkhan, master student, Abylkas Saginov Karaganda Technical University
e-mail: kakim08@mail.ru

Levshanov Ruslan, master student, Abylkas Saginov Karaganda Technical University
e-mail: kakim08@mail.ru