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«ХАЛЫҚ» ЖҚ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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STRUCTURAL SYNTHESIS OF HYDRAULIC IMPACT MECHANISMS WITH A COMBINED CONTROL BODY

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Abstract. The article is devoted to the study and substantiation of the choice of the optimal constructive scheme of the hydraulic impact mechanism that meets the requirements of the main technological purpose - generating a given energy and frequency of impacts with the most simplified structure with a sufficiently high efficiency energy conversion. This pursues the goal of choosing the basic structure for creating domestic hydraulic impact mechanisms that are distinguished by high manufacturability, reliability, compactness and patentability. The substantiation of the choice of the optimal scheme that satisfies the requirements of the task was made using structural synthesis, using the main provisions of the method of functional structure formation, which consists in explaining and describing the object under study, in which its elements and the links between them are analyzed within the framework of a single whole. Logically consistently using the methods of combining and substituting the functions of the elements of the impact mechanism, using various combinations of kinematic and structural links between them, imposing certain restrictions on the combination of links of these elements, as well as using the idea of changing the energy level of the limited structural volume of hydraulic working chambers due to the effect of compressibility and expansion working fluid, a constructive scheme was determined that meets the above requirements for further research. The scheme has a controlled working stroke chamber, an uncontrolled idle chamber with combined functions of the control element and using the effect of a hydraulic spring. This circuit is distinguished by the smallest number of elements and connections between them, which simplifies the design of the impact mechanism and reduces the number of transients, providing a more efficient transfer of energy to the tool.

Keywords: hydraulic impact mechanism; hydraulic perforator, structural synthesis; structure formation; structural formula

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БІРІКТІРІЛГЕН БАСҚАРУ ОРГАНЫМЕН ГИДРАВЛИКАЛЫҚ МҮШЕСІНІҢ МЕХАНИЗМДЕРІНІҢ ҚҰРЫЛЫМДЫҚ СИНТЕЗІ

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Аннотация. Мақала негізгі технологиялық мақсатты орындау талаптарына жауап беретін гидравликалық соққы механизмінің оңтайлы сұлбасын таңдауды зерттеуге және негіздеуге арналған – берілген энергияны генерациялау және энергияны түрлендірудің тиімділігі жоғары максималды жеңілдетілген құрылыммен соққы жиілігі. Бұл жоғары өнімділікпен, сенімділікпен және патенттілікпен ерекшеленетін отандық гидравликалық соққы механизмдерін құру үшін негізгі құрылымды таңдау мақсатын көздейді. Қойылған міндеттің талаптарын үйлесу, оңтайлы сұлбасын таңдаудың негіздемесі құрылымдық синтезді қолдана отырып, зерттелетін объектіні түсіндіру мен сипаттаудан тұратын функционалды құрылымдау әдісінің негізгі ережелерін қолдана отырып, оның элементтері мен олардың арасындағы қатынастар тұтастық шеңберінде талданады. Соққы механизмі элементтерінің функцияларын біріктіру және ауыстыру әдістерін логикалық дәйекті түрде қолданып, олардың арасындағы кинематикалық және конструктивті байланыстардың әртүрлі комбинацияларын және осы элементтердің байланыстарының тіркесіміне белгілі бір шектеулерді қойып, гидравликалық жұмыс камераларының шектеулі құрылымдық көлемінің энергетикалық деңгейін өзгерту идеясын қолдана отырып, жұмыс сұйықтығының сығылу және кеңею әсері арқылы жоғарыда аталған талаптарға жауап беретін конструктивті сұлбасы анықталды және қосымша зерттеулер үшін қолданды. Схемада басқарылатын жұмыс камерасы, басқару органының функциялары біріктірілген және гидравликалық серіппелі әсерді қолданатын басқарылмайтын бос камера бар. Бұл сұлба соққы механизмінің құрылысын жеңілдететін және өтпелі процестердің санын азайтатын, құралға энергияны тиімдірек беруді қамтамасыз ететін элементтер мен олардың арасындағы байланыстардың ең аз санымен ерекшеленеді.

Түйін сөздер: гидравликалық соққы механизмі; гидроперфоратор, құрылымдық синтез; құрылымның қалыптасуы; құрылымдық формула

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СТРУКТУРНЫЙ СИНТЕЗ ГИДРАВЛИЧЕСКИХ УДАРНЫХ МЕХАНИЗМОВ С СОВМЕЩЕННЫМ ОРГАНОМ УПРАВЛЕНИЯ

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Аннотация. Статья посвящена исследованию и обоснованию выбора оптимальной конструктивной схемы гидравлического ударного механизма, отвечающей требованиям выполнения основного технологического назначения – генерации заданной энергии и частоты ударов при максимально упрощенной структуре с достаточно высокой эффективностью энергопреобразования. Этим преследуется цель выбора базовой структуры для создания отечественных гидравлических ударных механизмов, отличающихся высокой технологичностью, надежностью, компактностью и патентоспособностью. Обоснование выбора оптимальной схемы, удовлетворяющей требованиям поставленной задачи произведено с применением структурного синтеза, использующего основные положения метода функционального структурообразования, заключающегося в объяснении и описании исследуемого объекта, при котором анализируются его элементы и взаимосвязи между ними в рамках единого целого. Логически последовательно используя приемы совмещения и замещения функций элементов ударного механизма, применяя различные сочетания кинематических и конструктивных связей между ними, наложения определенных ограничений на сочетание связей этих элементов, а также используя идею изменения энергетического уровня ограниченного конструктивного объема гидравлических рабочих камер за счет эффекта сжимаемости и расширения рабочей жидкости была определена конструктивная схема, отвечающая вышеприведенным требованиям для дальнейших исследований. Схема имеет управляемую камеру рабочего хода, неуправляемую камеру холостого хода с совмещенными функциями органа управления и с использованием эффекта гидравлической пружины. Данная схема отличается наименьшим количеством элементов и связей между ними, упрощающих конструкцию ударного механизма и уменьшающих число переходных процессов, обеспечивая более эффективную передачу энергии инструменту.

Ключевые слова: гидравлический ударный механизм; гидроперфоратор, структурный синтез; структурообразование; структурная формула

Introduction

Perspective of using hydraulic rock drills in the mining industry has been convincingly proven now. In this regard, it is advisable to focus on solving the issues of optimal structural and dynamic synthesis of hydraulic impact mechanisms (HIM), as the most complex and critical elements of drilling units (Yang et al., 2011; Lazutkin et al., 2015; Gorodilov et al., 2022; Chjin, 2010).

Experience in the operation of hydraulic rock drills shows that the functional reliability of the elements - the impact-piston group, the control unit, stabilizers of high and low pressure are limited. It is only 500-1000 operating hours.

In present time in the mining industry, in the construction industry, for repair of highways and the extraction of building stone, hydraulic rock drills of well-known manufacturers as Doofor (Finland), Montabert (France), Sandvik (Sweden), Everdigm (South Korea), Epiroc (Sweden), Furukawa (Japan), Soosan (South Korea), etc. are used.

Operating principle of these HIM is identical. In the basis of their construction, the main structural elements can be distinguished: a impact-piston group; the control unit; stabilizers of high and low pressure and tool (Ushakov, 2010; Mitusov, 2013; Kyzyrov et al., 2019; Yang et al., 2010). All these structural elements work in concert, but at the same time they experience high dynamic loads, are technologically difficult to manufacture due to high requirements for accuracy, tightness, quality of materials and surface hardening technology (Xu et al., 2015; Sokolski, 2017; Xu et al., 2016; Zhukov, 2023). In this regard, the issues of creating an impact mechanism that provides an effective cycle of pulsed energy conversion, low cost and manufacturability, in contrast to foreign ones with a complex control system, high requirements for manufacturing technology using expensive materials, are of particular relevance (Sokolsky, 2020; Azimov et al., 2023; Souilah et al., 2021; Yang et al., 2012).

Development of domestic manufacturing of HIM solves the problems of import substitution, increasing the technological level of domestic engineering and export orientation. For solving this problem, a scientific approach to the HIM structure formation was applied. Methods for evaluating and selecting structures for practical implementation of impact mechanisms that meet the criteria of economy, ease of constructive implementation, manufacturability and patent protection of the construction were used.

Materials and methods

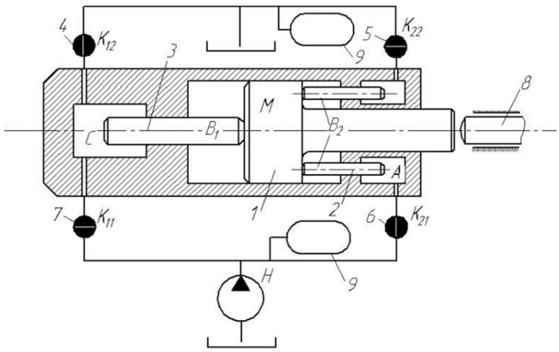
The creation of a new hydraulic impulse technic is preceded by research in the field of choosing a HIM construction scheme that meets the requirements of manufacturability and work efficiency. For choosing the constructive scheme, a structural synthesis of hydraulic impact mechanisms was used, using the main points of the method of functional structure formation, including the following steps: 1) selection of the studied object; 2) determination of its main functional purpose; 3) division of the object into structural elements; 4) obtaining structural formulas; 5) realization of formulas in constructive schemes; 6) selection of the optimal design scheme (Solod, 1968; Neroznikov, 1979).

The object of study is HIM, which is part of a hydraulic impulse system (HIS) designed to convert hydraulic energy into mechanical power impulses that carry out technological operations (drilling, crushing, etc.).

The necessary structural (functional) elements of HIM are (Figure 1):

- impact mass M (striker), perceiving a variable drive force in accordance with the phases of the working cycle, ending with the creation of a impact pulse on the tool;
- displacers B_1 and B_2, providing a force connection between the working fluid and the impact mass M, changing the volume of fluid in chambers A and C and acting as a source of drive force;
- valves K_i, performing the functions of power supply of the working chambers and the control unit that ensures the movement of the displacers in the specified directions and sequence.

The operating principle of HIM is as follows. When the inlet valve K_{21} and outlet valve K_{12} are opened, the working fluid enters the idle chamber A, acting on the displacers B_2. The striker moves to the left of the point of impact with the tool by the amount of the working stroke h, making an idle stroke. The movement must be impactless, economical, for a limited period of time $t_{i.st}$. When the inlet valve K_{11} and outlet valve K_{22} are opened, the working fluid enters in the working stroke chamber C, acting on the working surface of the displacer B_1, which transmits the force to the striker that moving until it hits the tool 8. The working stroke occurs. It is an acceleration of the striker to the speed of impact with the tool v_{im} in time $t_{w.st}$ and the conversion of kinetic energy $\frac{M \cdot \upsilon_{im}^2}{2}$ into a impact impulse on the tool, sufficient for effective crushing. The output parameters of the HIM are the impact energy $A = \frac{M \cdot \upsilon_{im}^2}{2}$ and impact frequency $n = \frac{1}{T}$, where $T = t_{i.st} + t_{w.st}$ is the operating cycle time.



1 - striker; 2 - displacers B_2; 3 - displacer B_1; 4-7 - valves K_{11}, K_{12}, K_{21}, K_{22}; 8 - tool; 9 - stabilizers of high and low pressure; H - pump

Figure 1. The structure of the hydraulic impact mechanism

The system-forming links between the functional elements of HIM are kinematic and constructive links. Kinematic link ensures the integration of functional elements into a single system to perform a given function. Conventionally, the kinematic link is denoted by the symbol (+). A constructive link allows you to combine two or more functions in one element while maintaining the system's operability and is denoted by the symbol ( ).

A different combination of kinematic and constructive links of functional elements leads to the formation of structural formulas that determine the structure of the impact mechanism. When certain restrictions are imposed on the combination of links between functional elements, it is possible to obtain structural formulas for various classes of impact mechanisms.

The process of obtaining structural formulas is called structure formation, as a result of which complete structures can be obtained that contain all the functional elements to ensure the working cycle and incomplete structures, in which some of the functional elements degenerate without transferring their functions to other elements (Solod, 1968; Neroznikov, 1979). The method of degeneration or substitution of functions can be realized in the following ways: 1) degeneration of elements K_{21} and K_{22} of the idle chamber control; 2) degeneration of elements K_{11} and K_{12} of the working stroke chamber; 3) combined degeneracy of elements.

Thus, using the accepted symbols of the elements and symbols of the links, it is possible to compose formulas for HIM structures that reflect the composition and nature of the links between the elements. A different combination of structural and kinematic links with elements leads to the formation of groups of valve, valveless and combined structures of impact mechanisms (Figure 2):

$$M + B_1 + B_2 + K_{11} + K_{12} + K_{21} + K_{22}; \quad (1)$$

$$M \cdot B_1 \cdot B_2 \cdot K_{11} \cdot K_{12} \cdot K_{21} \cdot K_{22}; \quad (2)$$

$$M + B_1 \cdot K_{11} \cdot K_{12} + B_2 + K_{21} + K_{22}. \quad (3)$$

Formulas (1) - (3) determine the structures of HIM schemes.

A distinctive feature of valve HIM is the absence of alignment links between the impact mass, displacers and valves. On the contrary valveless HIM is characterized by the presence of combination links between valves and other elements. A feature of combined HIM is that some of the valves are functionally combined with the impact mass and displacers, and some of them operate autonomously.

No matter of belonging to one group or another, all impact mechanisms are divided into single- and double-acting ones. In double-acting impact mechanisms both chambers communicate with a source of hydraulic energy, in single-acting mechanisms one chamber communicates.

For constructive realization and selection of the optimal structure, in the future, structure formation is considered on the example of valveless impact mechanisms or mechanisms with a combined control body as the most promising and universal HIM.

Structure formation makes it possible to obtain a number of formulas for HIM structures with a combined control body, in which the functions of the inlet and outlet valves are performed by the striker and displacers. To actuate the inlet and outlet valves of the working and idling chambers, you can use both the reciprocating movement of the striker and displacers, as well as other movements (rotary, turning, etc.). The first variant leads to the formation of autonomous mechanisms, the performance of the valves in which is provided by the system itself without additional elements. The second variant leads to the formation of mechanisms, the operation of valves in which is provided by additional elements, for example, a hydraulic motor for rotating the impact mass (Mitusov, 2013; Neroznikov, 1979; Uraimov et al., 2019).

To implement the principle of designing HIM schemes with a combined control body, it is necessary that the working and idle chambers, except the closedness and variability of the working volume have the elastic properties necessary to remember and maintain hydraulic signals for a certain time. During the operation of HIM, the working chamber must remember the hydraulic signal (pressure) when it is connected by an inlet valve to the pressure line. This chamber must accompany the movement of the striker until the next signal is given, which is possible due to the connection of the working chamber by outlet valve with the drain line. As a memory device, a hydraulic reservoir can be used, which provides additional elastic properties in the working chamber due to the compressibility of the working fluid.

The synthesis of HIM was carried out taking into account the following provisions:

1. In the working chambers only hydraulic energy is converted into mechanical work;
2. Complete structures are formed from the entire set of functional elements by composition based on kinematic, constructive and constructive-kinematic links;
3. Incomplete structures are formed from a reduced number of functional elements based on the above links;
4. The degeneration of any of the functional elements leads to the loss of system performance;
5. Substitution of degenerate functional elements is carried out only within the HIM.

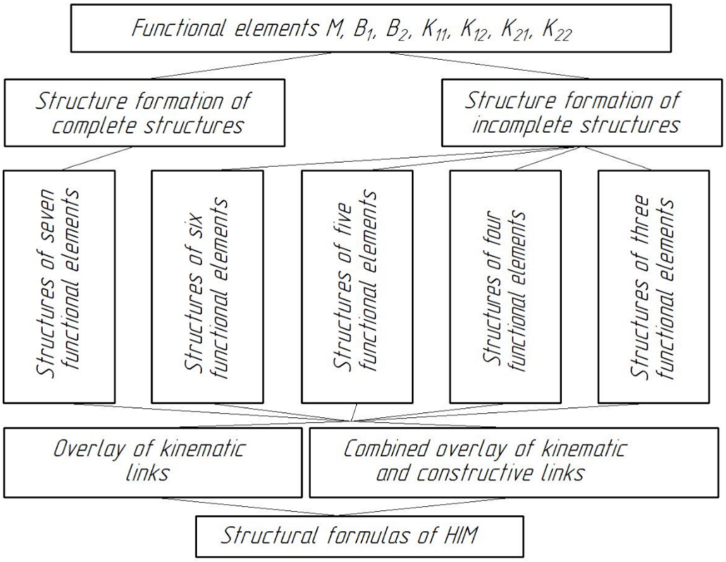
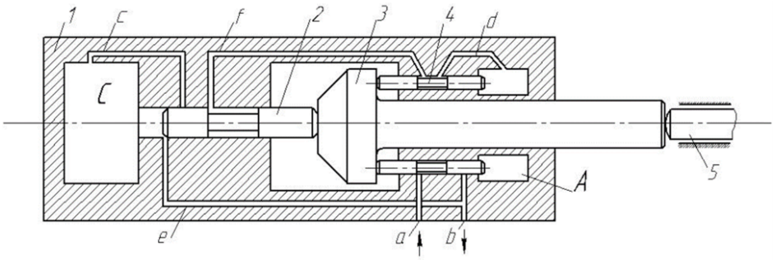


Figure 2. Scheme of HIM structure formation

Results and discussions

The constructive realization of the complete structures consists in the representation of the available elements and the distribution of the functions of the inlet valves and outlet valves between them. Figure 3 shows an example of a constructive scheme of HIM with a complete structure. The structure formula of mechanism is:

$$M + B_1 \cdot K_{11} \cdot K_{12} + B_2 \cdot K_{21} \cdot K_{22}. \quad (4)$$



A and C - chambers of idle and working strokes respectively;
1 - body; 2, 4 - displacers; 3 - striker; 5 - tool

Figure 3. Scheme of the impact mechanism with a complete structure

When fluid is supplied to chamber A, the striker 3, under the action of a force applied to the displacers 4, moves away from the tool 5 and, compressing the fluid in chamber C after the drain channel is blocked by displacer 2, makes idle stroke. At the end of idle stroke, due to the opening of the pressure channel «c» by displacer 2, chamber C communicates with the pressure line, and chamber A, due to the opening of the drain channel «b» by displacers 4, communicates with the drain line. There is a striker deceleration. Since the pressure in chamber C is equal to the main pressure, the striker begins its working stroke. First, the striker 3 moves when the inlet channel «c» and the drain channel «b» are opened. Then they overlap and further movement of the striker is carried out due to the expansion of the volume of fluid in chamber C, while the fluid in chamber A is compressed. At the end of the working stroke, the striker 3 strikes the tool. Chamber C, due to the opening of the drain channel «e» by the displacer 2, communicates with the drain channel, and chamber A, due to the opening of the inlet channel «d» by the displacers 4, communicates with the pressure line.

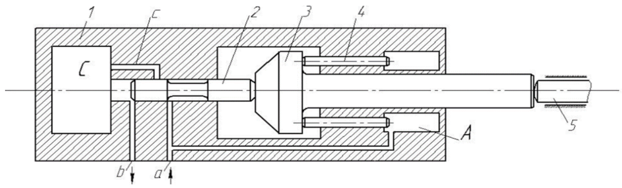
Degenerate structures are characterized by the fact that they can be deprived of one of the working chambers (when one of the displacers degenerates), as well as power control elements of one or two chambers (when one, two or three valves degenerate). The constructive implementation of degenerate structures is complicated by the fact that the degeneration of any element leads to a loss of efficiency of the constructive scheme. This is explained by the fact that the ability to control the movement of the striker is lost due to a breakdown in the connection of one or two chambers with the pressure or drain lines. With the constructive implementation of such structures, the operability of the schemes should be restored by creating new links instead the broken ones either due to the elements of the HIS subsystems or due to the elements of other external systems. The first method allows to restore the operability of impact mechanism schemes within one autonomous system without resorting to other surrounding systems for help. The second method leads to the emergence of non-autonomous (dependent) schemes, since it allows restoring the working capacity of impact mechanisms due to elements of external systems.

With the constructive implementation of formulas with degenerate elements of the control element of one of the chambers, the performance of HIM schemes is restored due to the constant connection of this chamber with the power source, i.e. with hydraulic transmission subsystem. An example of a constructive scheme with degenerate inlet and outlet valves of the idle chamber is shown in Figure 4. The formula for the structure of the mechanism is:

$$M + B_1 \cdot K_{11} \cdot K_{12} + B_2. \quad (5)$$

When fluid is supplied to chamber A, the striker 3, under the action of a pressure force constantly applied to displacers 4, moves away from tool 5. Further, compressing the fluid in chamber C, after blocking the drain channel «b» by displacer 2, striker makes idle stroke. At the end of idle stroke, due to the opening of pressure channel «c» by displacers 2, chamber C communicates with the pressure line. There is a striker deceleration.

Since the cross section of the displacer 2 is greater than the total area of the sections of the displacers 4, and the pressure acting on them is the same, the striker begins the working stroke. First, the striker 3 moves with the inlet channel «c» open, which then overlaps and the further movement of the striker 3 is carried out due to the expansion of the fluid in the chamber C. At the end of the working stroke, the striker 3 strikes the tool 5, and the chamber C, due to the opening of the drain channel «b» by the displacer 2, communicates with the drain line. Then the cycle repeats.



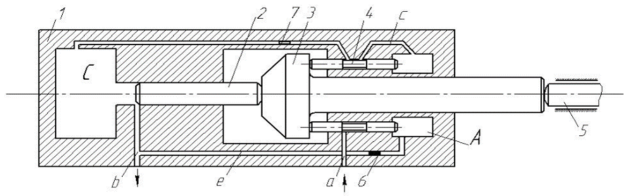
A and C - chambers of idle and working strokes respectively; 1 - body;
2, 4 - displacers; 3 - striker; 5 - tool

Figure 4. Scheme of the impact mechanism with degenerate valves $К_{21}$, $К_{22}$

With the constructive implementation of formulas with degenerate inlet valves or drain line of one or two chambers, the operability of the schemes of hydraulic impact mechanisms is restored due to the constant connection of these chambers through a separating element with a pressure or drain line. The separating element is subject to the requirements of limited inlet and outlet amount of fluid. As a separating element, a throttle with a constant flow area can be used. An example of a structural diagram with degenerate inlet and outlet valves for the working and idle chambers is shown in Figure 5. The formula for the mechanism is:

$$М + В_1 \cdot К_{12} + В_2 \cdot К_{21}. \quad (6)$$

When fluid is supplied to chamber A, the striker 3, under the action of force applied to the displacers 4, moves away from the tool 5. Further, compressing the fluid in chamber C, after blocking the drain channel «b» by displacer 2, striker makes idle stroke. At the end of idle stroke, the pressure in chamber C becomes equal to the main one due to its constant communication through the separating element 7 and channel «a» with the pressure line. In chamber A pressure is equal to value in the drain line, due to its constant communication through the separating element 6 and channels «e» and «b» with a drain line. There is a striker deceleration. Then the movement of the striker begins to the working stroke. During the working stroke, the striker moves under the action of a pressure force constantly flowing through the separating element 7 of the fluid, as well as due to its expansion in the chamber C. In this case, the fluid in the chamber A is partially compressed, and partially pushed out through the separating element 6 into the drain line. At the end of the working stroke, chamber A, due to the opening of the inlet channel «c» by displacers 4, is connected to the pressure line; chamber C due to the opening of the drain channel «b» by the displacer 2, is connected to the drain line. The striker 3 strikes the tool. Then the cycle repeats.



A and C - chambers of idle and working strokes respectively; 1 - body; 2, 4 - displacers; 3 - striker;
5 – tool; 6, 7 - separating elements (throttles)

Figure 5. Scheme of the impact mechanism with degenerate valves $К_{11}$, $К_{22}$

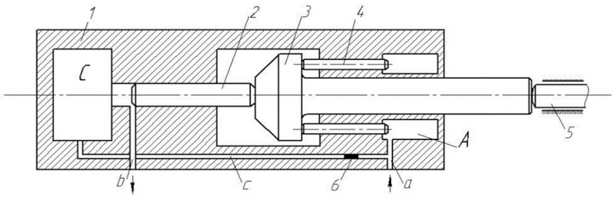
With the constructive realization of formulas with degenerate three valves, the operability of schemes of valveless hydraulic impact mechanisms is restored due to the constant connection of one of the chambers with a power source and the constant connection through the separating element of the other chamber with a pressure or drain line. An example of such constructive scheme is shown in Figure 6. The formula has the form:

$$M + B_1 \cdot K_{12} + B_2. \quad (7)$$

When fluid is supplied to chamber A, the striker 3, under the action of a pressure force constantly applied to displacers 4, moves away from tool 5 and, compressing the fluid in chamber C, after blocking the drain channel «b» by displacer 2, striker makes idle stroke. At the end of idle stroke, the pressure in chamber C becomes equal to the main one, due to its constant communication through the separating element 6 and channel «c» with the pressure line. The striker stops. Because the cross section of the displacer 2 is greater than the total area of the sections of the displacers 4, and the pressure acting on them is the same, the striker begins the working stroke. During the working stroke, the striker moves under the action of the pressure force of the fluid that constantly flowing through the separating element 6, as well as due to its expansion in the chamber C. At the end of the working stroke, chamber C, due to the opening of the drain channel «b» by displacer 2, communicates with the drain line, and the striker strikes the tool. Then the cycle repeats.

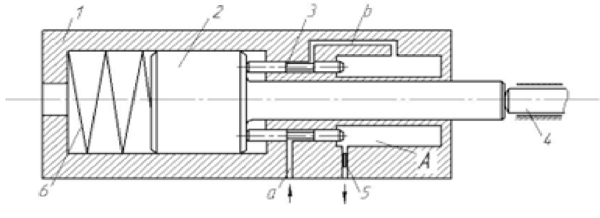
With the constructive realization of formulas with degenerate elements B_1, K_{11}, K_{12} or B_1, K_{21}, K_{22}, the operability of HIM schemes is restored by using elements of other environmental systems. An example of such constructive scheme is shown in Figure 7. The mechanism formula is:

$$M + B_2 \cdot K_{21}. \quad (8)$$



A and C - chambers of idle and working strokes respectively; 1 - body; 2, 4 - displacers; 3 - striker; 5 – tool; 6 - separating element (throttle)

Figure 6. Scheme of the impact mechanism with degenerate valves K_{21}, K_{22}



A - chamber of idle stroke; 1 - body; 2 - striker; 3 - displacers; 4 – tool; 5 - separating element (throttle); 6 - spring

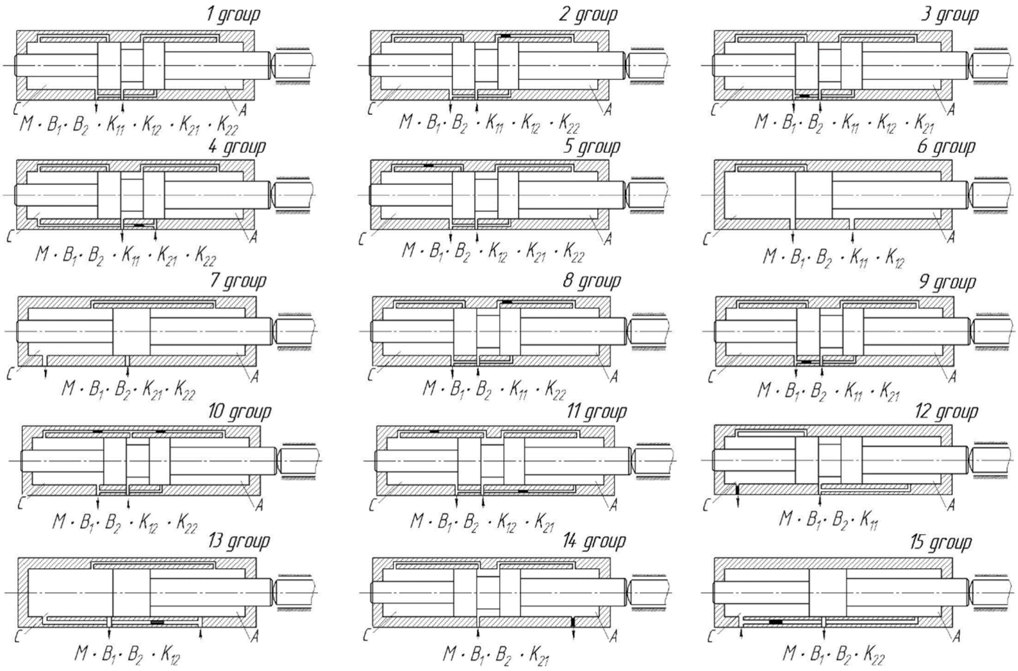
Figure 7. Scheme of the impact mechanism with degenerate elements B_1, K_{11}, K_{12}, K_{22}

When fluid is supplied to the chamber A, the striker 2, under the action of the force applied to the displacers 3, moves away from the tool and, compressing the spring 6, makes an idle stroke. At the end of idle stroke, the pressure in the chamber A becomes equal to the drain one, due to its constant communication through the separating element 5 with the drain line. The striker stops. Because the elastic force of the spring 6 acts on the striker 2, and the pressure in the chamber A is equal to the drain pressure, the working stroke begins. During the working stroke, the fluid in the chamber A is partially compressed, and partially pushed out through the separating element 5 into the drain line. At the end of the working stroke, chamber A, due to the opening of the inlet channel «b» by displacers 3, is connected to the pressure line, the striker strikes the tool 4. Then the cycle repeats.

Due to the significant number of structural formulas and schemes resulting from constructive implementation, the analysis and study of HIM schemes becomes more complicated. Therefore, it is more expedient to determine the structures of the constructive schemes of HIM, the working process in which would be identical, and then, grouping them, to conduct research.

Thus, in order to obtain a visual representation of the constructive schemes of HIM with a combined control body, according to the number and characteristics of the combined valves, the impact mechanisms can be divided into 15 groups, the analysis of which allows us to note the following (Figure 8):

- the first group is characterized by the presence of two controlled chambers, in which the change of the working volume occurs due to compression and expansion of the fluid in them, as well as their periodic connection with the pressure and drain lines in the working process;
- the second group is characterized by the presence of two controlled chambers, and the idle chamber is constantly connected by a throttle to the pressure line. The working process is characterized by the absence of a periodic process of fluid inlet into the idle chamber;
- the third group is characterized by the presence of two controllable chambers and the constant connection of the idle chamber through the separating element with the drain line. The working process is characterized by the absence of a periodic process of discharging fluid from the idle chamber;
- the fourth group is characterized by the presence of two controlled chambers and the constant connection of the working stroke chamber through a separating element with a drain line. Its working cycle is characterized by the absence of a periodic process of discharging fluid from the working stroke chamber;
- the fifth group is characterized by the presence of two controlled chambers and the constant connection of the working stroke chamber through a separating element with a pressure line. In the working cycle of this group, there is no periodic process of fluid inlet into the working stroke chamber;
- the sixth group is characterized by the presence of one controlled working stroke chamber, as well as the constant connection of the idle chamber with the pressure line or its absence at all. This group is characterized by the absence of the compression and expansion processes of the fluid in the idle chamber and its periodic connection with the pressure and drain lines;



A and C - chambers of idle and working strokes, respectively

Figure 8. Schemes of HIM with a combined control body

- the seventh group is characterized by the presence of one controlled idle chamber, as well as the constant connection of the working stroke chamber with the pressure line or its absence. This group is characterized by the absence of the compression and expansion processes of the fluid in the working stroke chamber and its periodic connection with the pressure and drain lines;
- the eighth group is characterized by the presence of two controlled chambers and constant communication through the separating elements of the idle chamber with pressure line and the working stroke chamber with drain line. The working cycle is characterized by the absence of a periodic process of fluid inlet into the idle chamber and its discharging from the working stroke chamber;
- the ninth group is characterized by the presence of two controlled chambers and constant communication through the separating elements of the working and idling chambers with the drain line. There is no periodic process of discharging fluid from both chambers;
- the tenth group is characterized by the presence of two controlled chambers and constant communication through the separating elements of the working and idle chambers with the pressure line. In the working cycle of this group, there is no periodic process of fluid inlet into the idle and working stroke chambers;
- the eleventh group is characterized by the presence of two controlled chambers and constant communication through the separating elements of the working stroke chamber with pressure line and idle chamber with drain line. The schemes of this group do not

have the process of fluid inlet into the working stroke chamber and its discharging from the idle chamber;

- the twelfth group is characterized by the presence of one controlled working stroke chamber and its constant connection through a separating element with a drain line, a constant connection of the idle chamber with a pressure line or its absence. The working cycle is characterized by the absence of a periodic process of discharging fluid from the working stroke chamber, as well as the absence in the idle chamber of the process of fluid compression and expansion and its periodic connection with the pressure and drain lines;
- the thirteenth group is characterized by the presence of one controlled working stroke chamber and its constant connection through the separating element with the pressure line, the constant connection of the idle chamber with the pressure line or its absence. The working cycle is characterized by the absence of a periodic process of fluid inlet into the working stroke chamber; the absence in the idle chamber of the process of fluid compression and expansion and its periodic connection with the pressure and drain lines;
- the fourteenth group is characterized by the presence of one controlled idle chamber and its constant connection through the separating element with the drain line, as well as the constant connection of the working stroke chamber with the pressure line or its absence. The working cycle is characterized by the absence of a periodic process of discharging from the idle chamber; the absence in the working stroke chamber of the process of fluid compression and expansion and its periodic connection with the pressure and drain lines;
- the fifteenth group is characterized by the presence of one controlled idle chamber and its constant connection through the separating element with the pressure line, the constant connection of the working stroke chamber with the pressure line or its absence. The working cycle is characterized by the absence of a periodic process of fluid inlet into the idle chamber; the absence in the working stroke chamber of the process of fluid compression and expansion and its periodic connection with the pressure and drain lines.

An analysis of the features that characterize each group showed that some features are common to all groups. Such a sign is the controllability of the working chambers, according to which impact mechanisms can be:

- with two controlled chambers (1 group);
- with two controlled chambers and with separating elements in them (2,3,4,5,8,9,10,11 groups);
- with a controlled working stroke chamber (group 6);
- with a controlled working stroke chamber and with a separating element in it (12.13 groups);
- with a controlled idle chamber (group 7);
- with a controlled idle chamber and a separating element in it (14.15 groups).

When choosing for further research a group of HIM schemes in relation to drilling machines, the main factor is the perfection of the structure and the process of energy conversion in the working chambers. Analysis of the features that characterizing the operating cycle of groups of schemes of impact mechanisms with separating elements have a direct connection of the pressure line through the working chamber and the separating element with a drain line. As a result, the working processes of the mechanisms of groups 2,3,4,5,8,9,10,11,12,13,14,15 are not economical due to the increased fluid flow due to the presence of fluid overflows through the throttles in the working cycle.

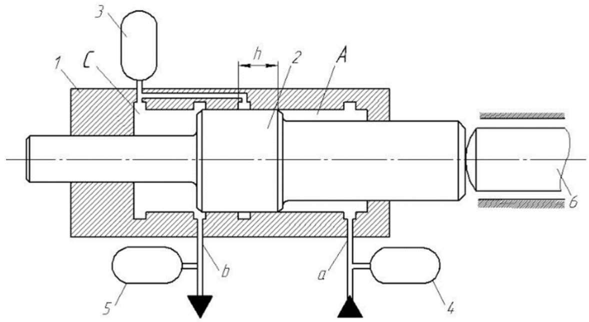
Groups 1, 6 and 7 will have a more economical energy conversion process, since they discharge fluid into the drain line after its preliminary expansion in the working chambers. From the point of view of the efficiency of the energy conversion process, groups 1, 6 and 7 are the same, however, from the point of view of structural perfection, simplicity of design, preference should be given to groups 6 and 7. The structural formulas of these groups have a smaller number of elements, and the schemes of their mechanisms contain only one controlled working chamber, equipped with an additional hydraulic capacity, which reduces the number of transients.

As a result of comparing the schemes of groups 6 and 7, it can be noted that the HIM with a controlled idle chamber cannot be recommended for constructive implementation due to a significant increase in the forces developed in the idle and working stroke chambers, on which inertial, volumetric and hydraulic losses are directly proportional and which, according to the task, should be minimal (Mitusov, 2013; Kyzyrov et al., 2019).

Conclusion

Thus, as a result of the structural analysis of HIM, the possibility of realization a simplified structural scheme with a combined control body using the effect of a hydraulic spring in the working chambers was revealed. Piston-driven working chamber A in the process of completing the working cycle is periodically connected to the high pressure hydraulic stabilizer 4 (at the end of the idle stroke) and to the low pressure hydraulic stabilizer 5 (at the end of the working stroke).

The result is a discrete increase or decrease of the energy level of the controlled working chamber. The working cycle is performed by changing the energy level of the additional volume of fluid 3 in the controlled working stroke chamber C (Figure 9).



;

A, C - chambers of idle and working strokes, respectively; 1 - body; 2 - piston-striker; 3 - additional volume of the working stroke chamber C; 4 - high pressure stabilizer; 5 - low pressure stabilizer; 6 - tool; a, b - pressure and drain channels, respectively; h – piston-striker stroke

Figure 9. Scheme of HIM with a combined control body

Stabilizers of high and low pressure are made in the form of calculated volumes of fluid, which also use the effect of a hydraulic spring (Raeder et al., 2021). Complex constructions of gas-fluid pressure stabilizers have been replaced by purely hydraulic stabilizers in an elastic steel shell. The structural scheme is distinguished by the smallest number of elements and connections between them, which simplifies the design of the impact mechanism and reduce the number of transients, which indicates a more efficient transfer of energy to the tool.

Thus, the structural synthesis of HIM made it possible to select the optimal constructive scheme of the impact mechanism that satisfies the requirements of the task.

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