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EFFECTIVENESS OF THE MULTIMODE HYDRODRIVE

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ЭФФЕКТИВНОСТЬ РАБОТЫ МНОГОРЕЖИМНОГО ГИДРОПРИВОДА

Purpose. Carrying out mathematical calculations generalized hydraulic systems. Considered schematics combined electrohydraulic drive its modes of operation used in many fields of technology., To provide high quality design work. This will significantly reduce the time to design development and testing of hydraulic systems. And also will help reduce costs for their development and testing.
Design/methodology/approach. The paper used graph-analytical approach to study the functioning of multiple objects. The approach used to assess the energy efficiency of hydraulic drive circuit design based exergy method.
Findings. The influence of operational factors on the loss of pressure in the hydraulic drive. As a result of studies comparing two drive circuit design, it was found that elements of increasing energy costs.
Originality/value. Applied graph-analytical method for calculating the hydraulic multi-hydraulic actuator. What helps determine which areas absorb considerable energy to the system in different modes.
Keywords: electrohydraulic drive, exergy, exergy method, energy, anergy.

INTRODUCTION. Combined Electrical hydraulic and built on the principle of its aggregates used in many fields of engineering [3]. They provide for the various modes. One example of this is the Electrical hydraulic unit, the two schemes presented in Figure 1, where we consider two versions of the drive with the valve booster (the manual) and with disconnection coupling. Combined drive mechanization (CDM) is designed to work as an actuator in the control flaps aircraft fixing them in position. The principle of operation of the drive is to ensure that mining moving flaps to a position that corresponds to the control signal. In native mode, the output shaft braking is ensured hydromechanical brake and reserve mode – from brake clutch motor.

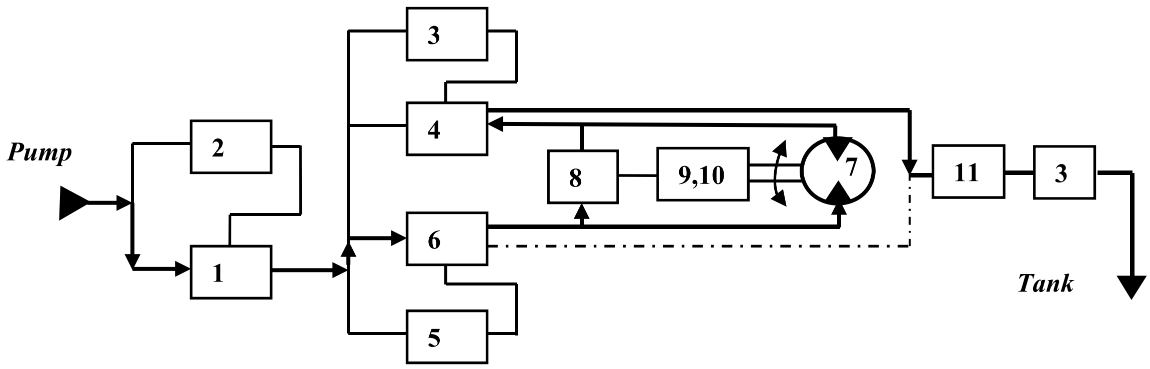

Fig. 1. Principle scheme CDM scheme with flap retaining

Installation of the valve booster (Fig. 1) is caused by the following: there is a range of unexpected pressure drop in the drive system, due to the connection of other customers in the hydraulic. It was decided to include in the system booster valve that adjusts the pressure at the inlet and discharge line to override the output, thus increasing the supply pressure of the drive.

The purpose of research. Carrying out mathematical calculations generalized hydraulic system. To provide high quality design work, in a significant reduction in terms of design and testing of hydraulic systems. Reduce the cost of their development and testing.

Method of research

Preproject predicting their performance in normal mode, to determine the advantages and disadvantages of the hydraulic actuator diagram.

The constructed under the scheme (Fig. 1) is as follows. At power to the input of hydraulic fluid falls under the end of valves 1 and 2. Spool valve 2 is moved, opening the saddle, hydraulic fluid pressure falls under the ends of the valves 3, 4, 5, 6 and booster valve 12. If a signal to release the flap, triggered electrohydraulic valve 4, from which hydraulic fluid under pressure enters the valve 3. Thus, the working fluid under pressure enters the motor 7, from the hydraulic motor to the valve 6 and a flow control valve 11 is at tank. At the same time hydraulic fluid from the valve 3, passes through the valve 10 to the brake hydromechanical 9, and the sensor signal is output coupling 8 "DISINHEBITED". After working the output shaft drive full-speed, trigger switches alarm "PULL OUT". Then off solenoid valves 2 and 4, and closes drain through valve 2. Shaft motor slows down, the limit switch is activated, deactivated alarm "DISINHEBITED". In the "RETRACTING" flap control signal to the solenoid 2 and 5. When the valve 5, spring cavity 11 is connected to the tank. Slide-valve 6 under pressure fluid is moved in the spring, the channel is connected to the hydraulic motor 7 and the valve 3 is connected to the valve 11. Follow the drive is similar to the work on the "PULL OUT" flaps.

The reserve mode, during the supplying power to the electric motor EM, with brake clutch, disinhibited motor shaft and rotates. Changing the direction of rotation of the output shaft is done by switching the polarity of the voltage applied to the motor.

To model the drive mode using flow graph theory [4] (or graphs flow signals), which correspond to the vertices of the graph sequence of operation elements CDM and arches – the transition elements from the "off" condition "works" or vice versa.

The principle of such a model can be explained by the following example: Consider a certain period of operation, the signal flow of the valve (position 1), the operation of the engine (position 2), off valve (position $\bar{1}$) and stop the motor – ($\bar{2}$). There are cycles of operation: $1-2-\bar{1}-\bar{2}$.

Sending a signal to trigger the valve and fill the hydraulic fluid channels – the arc ($\bar{2}-1$); the arc (1–2) – switching valve and the signal transmission from his operation of the motor; ($2-\bar{1}$) – signal transmission from the engine and turn the channel supply pressure valve on the shutdown; the arc ($\bar{1}-\bar{2}$) – signal transmission from the shut off valve to turn off the engine.

The calculation under such scheme is made separately for the processes of "PULL OUT" and "RETRACTING" for the two schemes (Fig. 1).

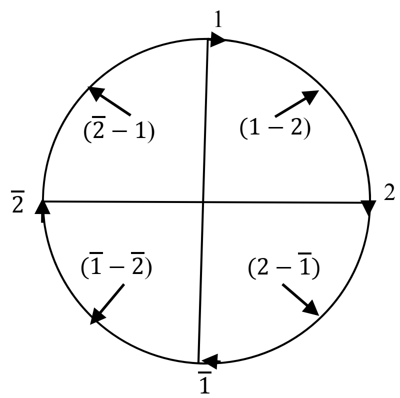

Fig. 2. Example of the construction of the graph

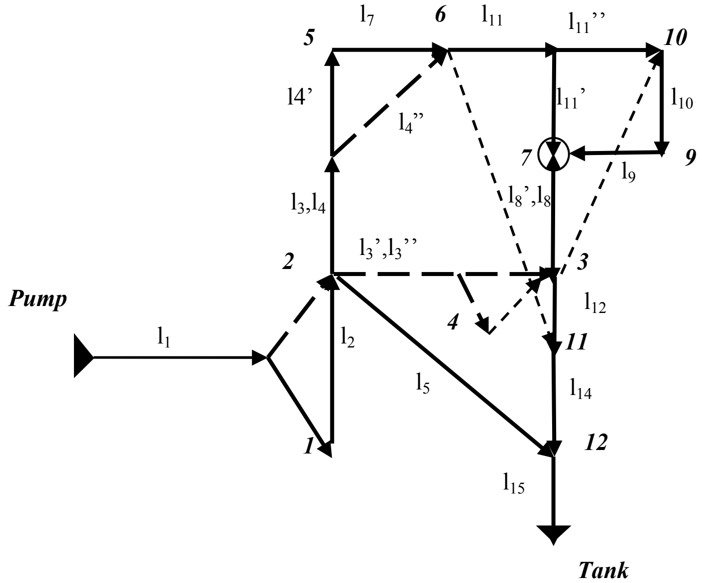

Fig. 3. Graf operating modes CDM to "PULL OUT" and "RETRACTING":

For the basic structure of the process (hydraulic) regime in accordance with the designation of the circuit elements, are elements of the sequence of operation of the system:

1) "PULL OUT":

$$pump-1,4-2-3-7,10-9,8-6-\prec 11\succ-\bar{1},\bar{4}-\bar{2},\bar{3}-\bar{7},\overline{10}-\bar{9},\bar{8}-\bar{6}-\prec\overline{11}\succ-\text{tank};$$

2) "RETRACTING":

$$pump-1,5-2-6-7,10-9,8-3-\prec 11\succ-\bar{1},\bar{5}-\bar{2}.\bar{3}-\bar{7},\overline{10}-\bar{9},\bar{8}-\bar{3}-\prec\overline{11}\succ-tank;$$

Structure of the process for the scheme (Fig.1):

1) "PULL OUT":

$$\text{pump}-1,4-2-3-7,10-9,8-6-\prec 11\succ-\prec 12\succ-\bar{1},\bar{4}-\bar{2},\bar{3}-\bar{7},\overline{10}-\bar{9},\bar{8}-\bar{6}-\prec\overline{11}\succ-\prec 12\succ-\text{tank};$$

2) "RETRACTING":

$$pump-1,5-2-6-7,10-9,8-3-\prec 11\succ-\prec 12\succ-\bar{1},\bar{5}-\bar{2},\bar{3}-\bar{7},\overline{10}-\bar{9},\bar{8}-\bar{3}-\prec\overline{11}\succ-\prec 12\succ-tank.$$

If the fluid flow through the motor is less than / greater than or supply pressure in the system below, then starts to work flow regulator (position 11) and valve booster (position 12). According to the of chainswe obtain graphs that specify the sequence of the drive components (Figures 3). Simulation designed to evaluate and compare the effectiveness of various schemes. Results of key parameters of the drive, taken into account in determining the future of energy losses in the system, with the initial data and the operating time on a particular mode, are listed in table 1.

Out a calculation of the drive after drawing a graph. The main parameters of the work was taken at a pressure in the hydraulic system 170 kg/cm^2, pressure drop133 kg s/ cm^2, flow rate of fluid through the actuator 15 L/min, rotation speed 200 r/min, the time of to " 37c and time "RETRACTING" the flaps 36s.

Power consumption is determined by the product of the response time on the power of each element according to the graph in Fig. 2. Useful work of the drive does not depend on the schematic solutions. Therefore the determination of the effectiveness of the scheme is based on the energy consumption of elements on which these schemes are different.

$$W_{sm\,1(a)}=\sum_{i=1}^{34}N_i^{`}\cdot t_i^{`};\ W_{sm\,1(б)}=\sum_{i=1}^{34}N_i^{``}\cdot t_i^{``};$$

$$\sum W_{sm\,1(a)}=N_i^{`}\cdot t_i^{`}+N_{i+1}^{`}\cdot t_{i+1}^{`}+\ldots+N_{i+33}^{`}\cdot t_{i+33}^{`}, \quad (1)$$

where $N_i^{`}$ – power of the corresponding element of, $i$ – corresponding line of, $t_i^{`}$ – time on the $i-s$ arc, the actuator from one element to another, $\sum W_{sm1(a)}$ – the total amount of energy used in the system.

Energy losses in the system (Fig. 1) to "PULL OUT" (I):

$$\sum_{i=1}^{34}\Delta W_{I\text{total}}^{`}=\Delta N_1^{`}\cdot t_1^{`}\cdot y_1^{`}+\ldots+\Delta N_i^{`}\cdot t_i^{`}\cdot y_i^{`}+\ldots+\Delta N_{34}^{`}\cdot t_{34}^{`}\cdot y_{34}^{`}. \quad (2)$$

Energy losses in the system (For schemes with disconnection coupling) to "PULL OUT" (I):

$$\sum_{i=1}^{34}\Delta W_{I\text{total}}^{``}=\Delta W_1^{``}+\Delta W_2^{``}+\ldots+\Delta W_i^{``}, \quad (3)$$

where $\Delta W_1^{``}=\Delta N_1^{``}\cdot t_1^{``}\cdot y_1^{``}$.

The relative energy efficiency of the schematic solutions drive:

$$B=\frac{\sum_{i=1}^{34}\Delta W_{I\text{total}}^{`}-\sum_{i=1}^{34}\Delta W_{I\text{total}}^{``}}{\sum_{i=1}^{34}\Delta W_{I\text{total}}^{``}}. \quad (4)$$

According to initial data and geometric parameters on the calculation of pressure losses in the system, taking into account the rheological dependencies working fluids, AMG-10 and Skaydrol.

In the course of the calculation takes into account parameters, modes, schematic solutions drive, multi-mode. Each mode was taken into account, what elements work and which channels are involved. It turned out that under different conditions and working conditions, the energy loss is different. This is explained by an example: if the mode "PULL OUT" work elements 1,2,4,3,10,9,11 and partially involved elements channels 6 and 10, and the valve 5 and the channel connecting it to the valve 6 – unused. And in the "RETRACTING" the lips is on the contrary, partly elements channels 3 and 10, the valve 4 and the channel connecting it to the valve 3.

Simulation results of the two schemes in the normal mode of work and with the entry requirements for the accuracy and efficiency of operation, we can draw the following conclusions:

- unused elements provide additional energy losses in the system, and at low temperatures the working fluid, and the additional loss of the system response time (due to the dead-end sections at which the viscosity is very high). The calculation of pressure losses in accordance with the count made by the formulas:

$$\Delta p_{(\overline{11}-2)}=\Delta p_{(lin.)}+\Delta p_{(in.velv.st.)};$$

$$\Delta p_{(2-1)}=\Delta p_{(lin.)}+\Delta p_{(ex.velv.st.)}+\Delta p_{(in.velv.1;)};\ \Delta p_{(1)}=\Delta p_{(velv.1)};$$

i etc.

$\Sigma\Delta p_{(sistems)}=\Delta p_{(pump)}+\Delta p_{(2-1)}+\ldots+\Delta p_{(\tan k)}$. The pressure loss in the system, the energy losses were calculated by formulas (1-3), according to the response time of each portion of the drive. According to the graph (see Figure 3), the data obtained for the regime "PULL OUT" from the process fluid AMG-10 at temperature +20 ^{0}C the distribution of pressure losses of power and energy to the system elements.

As a result of pressure loss at different schematic CDM solutions showed an increase in the pressure loss in the system with booster valve. This is because the VB is located on the discharge line of the unit and performs operational function only at low pressure, and the rest of the work – a significant part of the energy absorbed. In Fig. 4 shows the comparative distribution of energy loss of the drive in the "PULL OUT" at different rates of temperature with the inclusion of VB. Energy losses are considered to drive circuit in one mode.

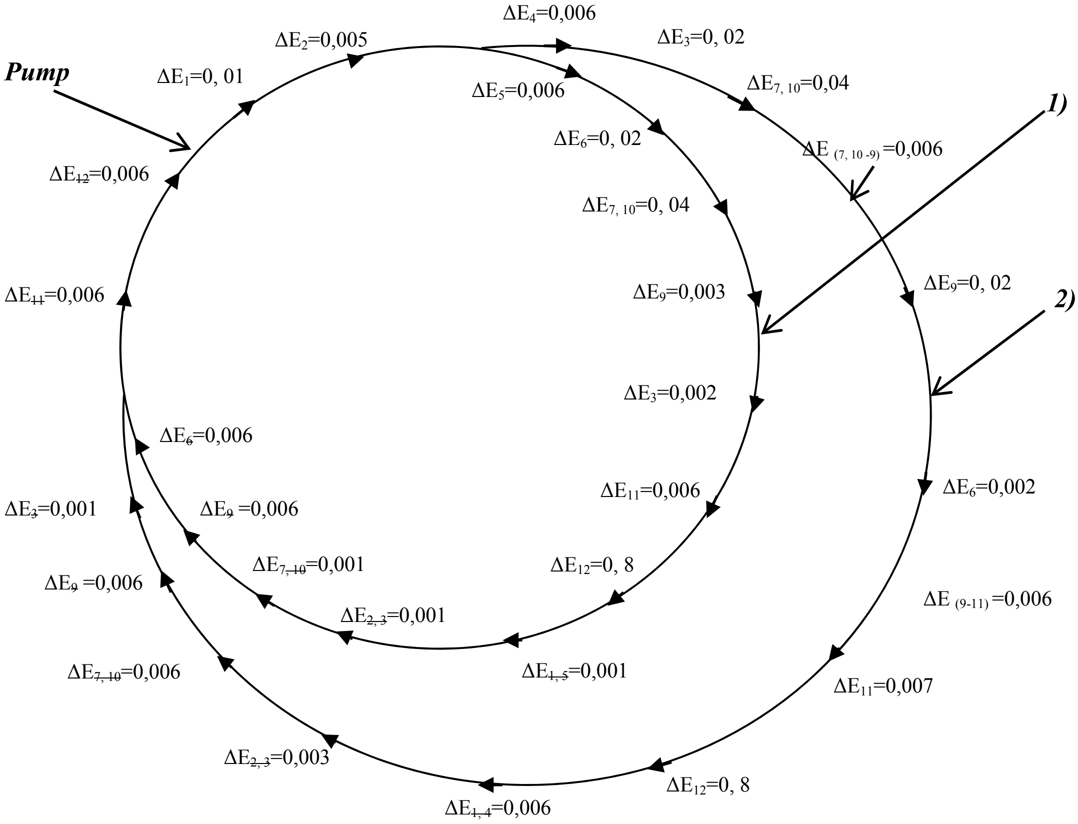

Fig. 4. The distribution of energy loss of the drive with the VB, which operates in the "PULL OUT" at temperatures -20 ^{0}C

Comparative graph shows that valve booster actuation (Fig. 4, position 12) cause additional loss of energy in the system. Comparing the predicted loss of energy from the schematic solutions with different working fluids are shown in Table 2.

Table 1

Comparative calculations of schemes for the booster valve

The element on the graph	Mode "PULL OUT" / "RETRACTING"	Energy loss, kJ ΔE	The element on the graph	Mode "PULL OUT" / "RETRACTING"	Energy loss, kJ ΔE
1	+	0,006	$\overline{12}$ - 1	+	0,004
2	+	0,005	1 - 2	+	0,006
3	+ / -	0,03 / -	2 - 4	+	0,004
4	- / +	- / 0,03	2 - 5	+	0,004
5	+ / -	0,05 / 0,003	4 - 3	+ / -	0,004 / -
6	- / +	0,003 / 0,05	5 - 6	- / +	- / 0,004
7	+	0,03	3 - 7,10	+	0,005
9	+	0,02	6 - 9	+	0,001
10	+	0,01	9 - 11	+	0,003
11	+- / +-	0,003⇒0,05	11 - 12	+	0,001
12	+- / +-	0,004⇒0,8	12 - $\overline{1,3}$	+	0,001

Table 1 (continued)

Comparative calculations of schemes for the booster valve

$\overline{1}$	+	0,001	$\overline{1,3}$ - $\overline{2}$	+	0,001
$\overline{2}$	+	0,001	$\overline{2}$ - $\overline{4}$	+	0,001
$\overline{3}$	+- / +-	0,003	$\overline{4}$ - $\overline{7,10}$	+	0,001
$\overline{4}$	+- / +-	0,003	$\overline{7,10}$ - $\overline{9}$	+	0,001
$\overline{5}$	+ / -	0,003 / -	$\overline{9}$ - $\overline{11}$	+	0,001
$\overline{6}$	- / +	- / 0,003	$\overline{11}$ - $\overline{12}$	+	0,001

As a result, identifying energy losses in the systems calculated the coefficient of relative energy efficiency solutions B_{sist} schematic:

$$B_{\text{sist}} = \frac{\sum_{i=1}^{34}\Delta W'_{I\text{total}} - \sum_{i=1}^{34}\Delta W''_{I\text{total}}}{\sum_{i=1}^{34}\Delta W''_{I\text{total}}} = \frac{(\Delta W'_1 + \Delta W'_2 + ... + \Delta W'_i) - (\Delta W''_1 + \Delta W''_2 + ... + \Delta W''_i)}{\Delta W''_1 + \Delta W''_2 + ... + \Delta W''_i}. \quad (5)$$

Obtained by the formula (5) the values of the relative energy efficiency are an indication of the schematic solutions to the VB and the decision with the coupling of separation (Table 3).

For example, energy efficiency schematic solutions at -20 ^{0}C with working fluid Skaydrol:

$$B_{\text{sist}} = \frac{0{,}118 - 0{,}108}{0{,}118} \approx 8\%.$$

Value B_{sist} indicates that the schematic solution coupling of separation, at operating temperatures -20^{0}C on ~ 8%, at +20^{0}C on ~ 7%, at 60^{0}C on 7% more efficient than the scheme with the use of manual working fluids AMG-10 and Skaydrol.

The next step for the modeling and forecasting of energy efficiency of the drive, you can spend energy analysis, which is based on the criterion of exergy, which characterizes the efficiency investigational device CDM.

Exergy analysis on how to find the efficiency of using the formula [1]:

$$\eta = \frac{\text{exergy}}{\text{energy} + \text{anergy}},$$

$$\eta_{sist1} = \frac{\sum_{i=1}^{34} W'_{Itotal}}{\sum_{i=1}^{34}\Delta W'_{Itotal} + \sum_{i=1}^{34} W'_{Itotal}}$$ – efficiency of the system 1, where $\sum_{i=1}^{34}\Delta W'_{Itotal}$ – anergy, that is, all the energy losses in the system, $\sum_{i=1}^{34} W'_{Itotal}$ – exergy, that is, the energy that goes into useful work (operation of valves, etc.). Accounting efficiency for such a schematic solutions must be different for each mode. To anergy in reviewed schematic solutions combined drive mechanization include:

Table 2

Relative efficiency of B_{sist}

	B_{sist}	
Temperatures, ^{0}C	AMG -10	Skaydrol
-20	0,0805	0,0771
+20	0,0709	0,0696
+60	0,0695	0,0779

- energy, which is caused by pressure losses in length (loss of pressure in the hydraulic lines) and local [3] (for example, the "cleaning" works only 2 valve, and the valve 4 is also involved – through his window to drain fluid flows, and vice versa : valve 4 has to "PULL OUT", and through valve 2 – liquid goes to the plums, and the loss of energy in these valves are anergy and are $\Delta W_{3,4}=0{,}002$ *kJ)*.
- energy that is lost with the loss in drainage channels (see Figure 1 – lines from the valves 1,2,4 and 5 dashed);
- the energy that is spent on heating unit at low environmental temperatures (for example, while flying at -60 ^{0}C, the unit is cooled to -40 ^{0}C and the reaction time of the drive increases ≈ 3 to 12 position) [3].
- energy that is lost during operation in a retaining valve.

Loss reduction can be achieved by decreasing the length of the size of the unit, a reduction of energy loss can be achieved by cooling the thermal insulation of the drive and the energy loss in the VB – addresses upgraded schematic solution.

When the schematic solution (Fig. 1) predict energy losses at -20^{0}C $\Delta W_{кп}$=0,009315 kJ, at temperatures +20^{0}C $\Delta W_{кп}$=0,003625 kJ, at temperatures +60^{0}C $\Delta W_{кп}$=0,002994 k J.

When all the energy loss of the drive system, which cannot be used and those that are spent on the valuable work of the system, we can evaluate the effectiveness of multi-mode drive.

CONCLUSIONS

The problem of evaluating the effectiveness of the stage of forming circuit design combined drive mechanization by considering two options that provide the same management "PULL OUT" and "RETRACTING" flaps.

To assess the effectiveness of circuit design with the drive mode built Graphic analytical model that build on the elements of a distributed evaluation design power and energy losses with a time of action.

The calculations of energy loss CDM found that the change in the rheological properties of the fluid (AMG-10 and Skaydrol) in different operating conditions affect the energy loss is approximately the same (± 1%).

According to the results of the study, the coefficient of relative effectiveness B_{sist} circuit design combined drive mechanization, which is based on energy elements on which these schemes are different. Found that the decision of CDM schematic using disconnection clutch operating temperatures-20^{0}C by ~ 7%, at 20^{0}C for about 8%, at 60^{0}C for 7% more efficient than the schematic solution booster valve. These values are valid for fluid AMG-10 and for Skaydrol.

Conducting energy analysis made it possible to define a schema element, which causes a decrease in energy efficiency by increasing the share of anergy. Using a booster valve that works no more than 3% of the time, and all the rest of the time consumes a significant amount of energy that forms component of anergy, which can expect the developer to design and upgrade the drive to improve its efficiency.

Анотація. *Розглянуто схемні рішення комбінованого електрогідравлічного приводу, його режими роботи, що використовуються в багатьох областях техніки. Ціллю дослідження являється проведення математичних розрахунків узагальнених гідравлічних систем, щоб забезпечити високу якість проектних робіт, в значному скороченні у перед проектній розробці та випробування гідравлічних систем, що дасть змогу знизити витрати на їх розробку і тестування. У роботі використаний графо-аналітичний підхід до дослідження функціонування багатоелементних об'єктів. Підхід застосовано для оцінки енергетичної ефективності схемних рішень гідравлічного приводу на основі ексергетичного методу. Досліджено вплив експлуатаційних факторів на втрати тиску в гідросистемі приводу. В результаті проведеного дослідження порівняння двох схемних рішень привода було з'ясовано, які елементи системи збільшують енерговитрати.*
Ключові слова: електрогідропривод, ексергія, ексергетичний метод, енергія, анергії.

Аннотация*. Рассмотрены схемные решения комбинированного электрогидравлического привода, его режимы работы, используемые во многих областях техники. Целью исследования является проведение математических расчетов обобщенных гидравлических систем, чтобы обеспечить высокое качество проектных работ, в значительном сокращении в разработке и испытании гидравлических систем, что позволит снизить затраты на их разработку и тестирование. В работе использован графо-аналитический подход к исследованию функционирования многоэлементных объектов. Подход применен для оценки энергетической эффективности схемных решений гидравлического привода на основе эксергетической метода. Исследовано влияние эксплуатационных факторов на потери давления в гидросистеме привода. В результате проведенного исследования сравнение двух схемных решений привода было выяснено, какие элементы системы увеличивают энергозатраты.*
Ключевые слова: електрогидропривод, эксергия, эксергетический метод, энергия, анергии.

1. *Бродянский В.М.* Эксергетический метод термодинамического анализа. – М.: Энергия, 1973. – 296 с. – Библиогр. : С. 276-294.
2. *Терентьев Е. Ф.* Эксергия как критерий оценки эффективности функционирования технологических систем / Е. Ф. Терентьев, С. И. Матвиенко // Экология северных территорий России. Проблемы, прогноз ситуации, пути развития, решения: матер. междунар. конф., Архангельск, 17-22 июня 2002 г. Т. 2. – Архангельск: Ин-т экол. пробл. Севера УрО РАН, 2002. - С. 230-233.
3. *Яхно О.М.* Ексергетичний аналіз привода механізації крила літака / О. М. Яхно, О. П. Губарев, А. М. Муращенко та ін. // – Промислова гідравліка і пневматика.: Всеукр. наук.-техн. журн. / Вінниц. держ. аграр. ун-т ; Асоц. спеціалістів пром. гідравліки і пневматики. – К.: [б. и.], 2011. – № 4(34). – С. 45-49.
4. *Яхно О.М.* Введение в мехатронику: Учеб. Пособие для студ. спец. «Гидравл. и пневмат. машины», «Прикладная механика» / О. М. Яхно, А.В. Узунов, А.Ф. Луговской и др. – К.: НТУУ "КПИ", 2008. – 528 с.

REFERENCES

1. *Brodyanskij V.M.* Exergeticheskij metod termodinamcheskogo analiza (Exergy method of thermodynamic analysis) Moscow, 1973. 296 p.
2. *Terentiev E.F.* Exergija kak kriterij otsenki funktsionirovanija tehnologicheskih system (Exergy as a criterion for evaluation of the functioning of technological systems), Arkhangelsk 17-22 June 2002. P. 230-233.
3. *Yakhno O.M.* Exergeticheskij analiz privoda mehanizatsiya krila litaka (Energy analysis of the drive mechanization wing) O. M. Yakhno, O. P. Gubarev, A. M. Murashchenko ta in. Кiev, 2011. No 4(34). P. 45-49.
4. *Yakhno O.M.* VVedenie v mehatroniku (Introduction to mechatronics), Кiev, 2008. 528 p.