SATBAYEV UNIVERSITY
Journal of Energy, Mechanical Engineering and Transport
Volume 1 (2024), Issue 3, 1-5

https://doi.org/10.51301/jemet.2024.i3.01

Title Modeling a new pumping machine design in Kompas

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Abstract. The article deals with crank-slider mechanisms of the 3rd class, implementing the required cyclogram with an approximate stand, the output link of which moves along the guide, the position of which is set. Analytical expressions for calculating the parameters of the kinematic scheme of the mechanism are obtained. Both flat four-link and more complex multi-link crank mechanisms are used in crank presses. During one reciprocating movement (stroke) of the slider, the input crank makes a complete revolution, which corresponds to the cycle of the press. Twice per cycle, at extreme positions, the speed of the slider should be zero, thus, the movement of the output link is accompanied by the appearance of inertial forces. Technological requirements determine the specific nature of the movement of the slider, which is provided by the appropriate structure of the actuator or by varying the size of its links.
Keywords: *modeling, pumping machine, rod pump, kinematic diagram, analysis, synthesis.*

1. Introduction

As a drive for rod pumps, balancing pumping machines are traditionally used, which have a simple, well-studied design and, in comparison with other drives, an economical, repairable design [1, 2, 3-7, 8, 9, 10].

In the works [11, 12], a methodology, algorithms and a package of application programs were created for kinematic and kinetostatic calculations and optimal balancing of the converting mechanisms of the hydraulic lift rod with a two-arm balancer and rotor balancing. The methodology and programs were used to calculate pumping machines PShN6-2.5-3500 and RPD 8-3-4500 with maximum loads in the wellhead seal of 6t and 8t.

An alternative possibility is to use straight-line guide mechanisms as a conversion mechanism. Thus, the advantage of the SK «with a floating balancer» was confirmed by experience in the development and operation of the 2SKM7 type, created on the basis of the SKN70-3012 pumping machine [2, 11]. The Evans lemniscate rectangle is used as a transforming mechanism. Another example of the use of rectilinear guide mechanisms is the recent development of Minnesota [13], in which the reciprocating movement of the rod suspension is provided by the Roberts mechanism. The goal of the development is to initially eliminate the massive and complex «horse head» in typical installations [6]. Moreover, the overall dimensions in both cases turned out to be almost two times smaller compared to the prototypes. There are other types of rectilinear guiding mechanisms that could also be effectively used [11, 12, 13, 14, 15]. But a systematic study of them in relation to the problem under consideration has never been carried out.

Work [16] sets out the general principles of structural analysis of mechanisms, features of kinematic analysis using Lagrange variables and dynamic analysis based on the energy model of mechanics with the fulfillment of the law of conservation of energy on any elements and for the mechanism as a whole for any time interval.

Here, the methods of kinematic analysis and synthesis of complex gear mechanisms, metric synthesis according to given conditions of lever mechanisms, their kinematic, force calculations and balancing are described in detail [17].

The study [18] examines ways to increase the service life of parts of pressing mechanisms. The balancing mechanism of the upper roll significantly affects the rolling accuracy and operating conditions of the pressing device. Calculations of the balancing mechanism are usually limited to the case of static balancing for some average position of the mechanism. However, the mechanism operates in a dynamic mode, which means that large masses accelerate and decelerate in short periods of time, and, in addition, friction forces in kinematic pairs have a significant impact on the operation of the mechanism. All this significantly affects the service life of the pressing mechanism parts. Therefore, this article examines the dependence of the rebalancing coefficient on the position of the mechanism; the dependence of the force of tightening the screw to the nut on the position of the mechanism, taking into account the friction forces during the convergence and separation of the rolls, as well as taking into account the inertia forces during braking and acceleration; a refined calculation of the balancing device was performed taking into account friction forces and dynamic operating conditions of the mechanism.

Article [19] considers class 3 crank-slider mechanisms that implement the required cyclogram with an approximate stop, the output link of which moves along a guide whose position is specified. A graphical synthesis method has been developed that allows one to determine the initial values of free parameters. Analytical expressions for calculating the parameters of the kinematic diagram of the mechanism are obtained. Both flat four-bar and more complex multi-bar crank mechanisms are used in crank presses. During one reciprocating movement (stroke) of the slide, the input crank makes a full revolution, which corresponds to the press operating cycle. Twice per cycle, at extreme positions, the speed of the slider should be zero, thus, the movement of the output link is accompanied by the appearance of inertial forces. Technological requirements determine a certain nature of the movement of the slider, which is ensured by the appropriate structure of the actuator or by varying the size of its links.

Article [20] is devoted to the study of the features of using the analytical method of kinematic analysis of lever mechanisms. For mathematical modeling of multi-link lever mechanisms, a number of analytical methods are used, based on obtaining formal mathematical expressions that describe position functions in the form of functions of rotation angles of moving links or in the form of functions of movement of characteristic points of the mechanism. As an example, the article analyzes the multi-link hinge-lever mechanism of a knitting machine using the «Given-Find» computing unit of the MathCAD application computer program.

In work [21], the dynamics of the mechanism of conventional pumping pumps is analyzed.

1.1. Design of the rocking machine mechanism

To improve the optimal design of pumping machines (SK) based on rectilinear-guide transforming mechanisms; Model in the universal software KOMPAS to achieve the optimal design of pumping machine (SK) structures using modern current methods for calculating mechanical systems, and also find optimal solutions for purposes with the main criteria, and which meet the current requirements for CAD.

Rocking chairs are installed on specially prepared foundations (usually concrete blocks) and can be either monolithic (concrete or reinforced concrete) or prefabricated (made of concrete blocks or metal). These include platforms, racks and control stations.

The pumping machine consists of a frame, racks, cranks, connecting rods, balancers, electric motors, gearboxes, counterweights and brakes;

The frame on which the pumping machine equipment is located is made in the form of two runners made of rolled metal, connected by cross members, and contains special supports for the gearbox.

The balancers are made of four-sided rolled steel of a pyramidal shape to transmit the reciprocating motion of the boom column. They are also made from rolled I-beam steel.

The crossbar connects the crank mechanism with the rocker arm and is structurally made in the form of a straight beam made of rolled steel.

The crank mechanism serves to convert the rotational motion of the gearbox shaft into the reciprocating motion of the rocker arm and consists of two connecting rods and two cranks with counterweights.

The cranks are the leading links in the rocker mechanism conversion mechanism and are bored out to change the stroke length of the wellhead rod. The cranks are equipped with a counterweight, which is moved by a removable device inserted into a transverse groove in the base of the counterweight.

The balancer has a head on the front arm, to which the boom column is attached via a cable suspension. The rear boom is connected to the crank by two connecting rods through a lifting beam and a lifting beam support on which a counterweight (weight) is mounted. The crank is mounted on the shaft of the low-speed gearbox. Balancing is necessary to reduce the inertial forces on the balancer that arise due to the uneven movement of the counterweights. Rocker arm balancing can be achieved by placing the necessary counterweights either on the rear arm of the rocker arm or on the crank. Therefore, a distinction is usually made between balancing low-capacity rocker arms, high-capacity cranks, and combined balancing. There are also balancers with hydro pneumatic and pneumatic balancers, but they are more complex, more expensive and more metal-intensive, despite their slightly smaller overall dimensions. The transmission of the pumping machine consists of a gearbox and a V-belt drive. As a rule, electric motors are used for drive, but internal combustion engines can also be used [8, 9].

The drive mechanism of the simulated pumping machine includes elements such as two cranks 3 and two connecting rods 4 located. Between the cranks and connecting rods there are four bearing housings 5, four supports 6 located at the second end of the connecting rods, on the right side of the drawing, link AB 7, two bearing housings located in position 8, perpendicular to the connecting rods, two OS links are also shown. The axles are in positions 10 and 11, two bushings are in position 12, and the second bearing is in position 15.

The rocker counterweight is in position 16, the weight rod is in position 17, and the four weights are in position 18.

The drive mechanism of the pumping machine works as follows. Torque is transmitted from the gearbox to the crank shaft 1. The rotation of the crank 1 through the connecting rod 2 is transmitted to the connecting rod 3, as well as to both rocker arms 6 on the rear arm 5. The connecting rod 3 acts on the rocker arms 11 to fix both rocker arms 5 on the rear arm and 6 on the front arm, the rocker arms 11 perform an oscillatory motion in an arc, the head 10 on the connecting rod 3 of the front arm 4 of the column performs a rectilinear reciprocating motion.

The drive mechanism of the simulated pumping machine includes elements such as two cranks 3 and two connecting rods 4 located. Between the cranks and connecting rods there are four bearing housings 5, four supports 6 located at the second end of the connecting rods, on the right side of the drawing, link AB 7, two bearing housings located in position 8, perpendicular to the connecting rods, two OS links are also shown. The axles are in positions 10 and 11, two bushings are in position 12, and the second bearing is in position 15.

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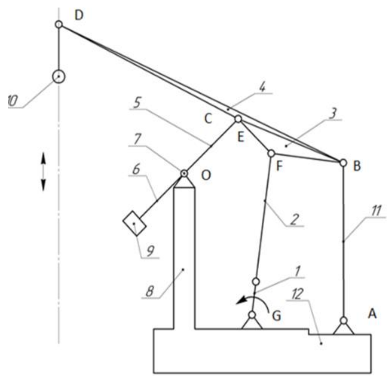

Figure 1. Diagram of the drive mechanism of sucker rod pumping units in the upper position

The drive mechanism of the pumping machine works as follows. Torque is transmitted from the gearbox to the crank shaft 1. The rotation of the crank 1 through the connecting rod 2 is transmitted to the connecting rod 3, as well as to both rocker arms 6 on the rear arm 5. The connecting rod 3 acts on the rocker arms 11 to fix both rocker arms 5 on the rear arm and 6 on the front arm, the rocker arms 11 perform an oscillatory motion in an arc, the head 10 on the connecting rod 3 of the front arm 4 of the column performs a rectilinear reciprocating motion.

Dimensions: LAB=1115 mm, LBD=2360.35 mm, LBD= 1019.205 mm, LBC=868.28 mm, LCD=1494.10 mm, LBC=868.28 mm, LOC=548.95 mm, LCE=533.729 mm, LEF=1163.4655 mm, LFG=454.879 mm. A geometric model of all structural components of the mechanism was designed in Kompas3D.

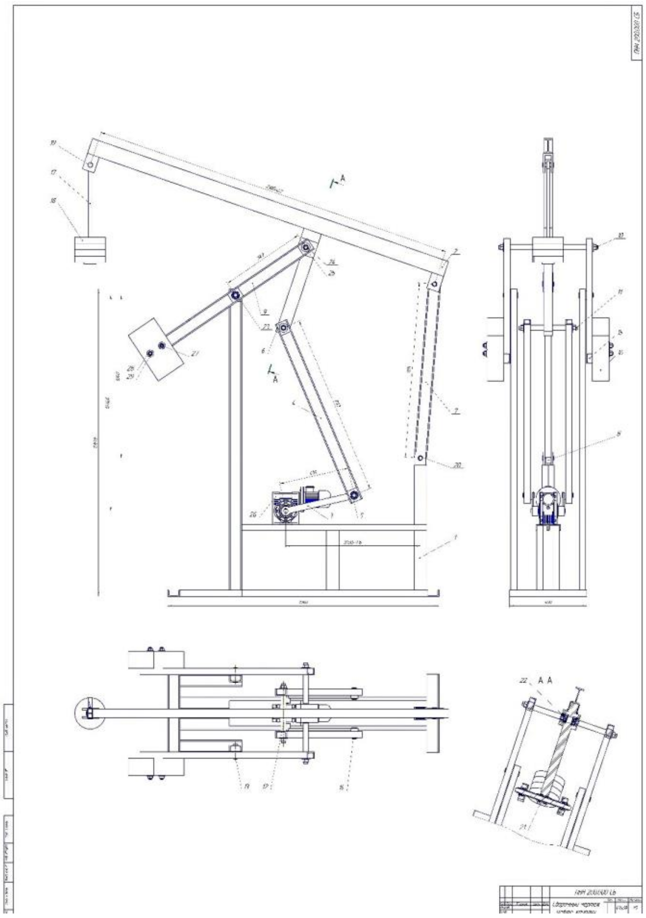

Figure 2. Assembly drawing of the pumping machine

Table 1. Specification

No	Name	mount
	Documentation	
	Assembly units	
1	AD Rama	1
2	AD working mechanism	1
	Details	
3	Crank	2
4	Connecting rod	2
5	Bearing housing 3	4
6	Support 1	4
7	Link AB	1
8	Bearing housing 4	2
9	OS link	2
10	Axle new	1
11	Axis 2	1
12	Bushing 1	2
13	Finger 1	2
14	Finger 2	2
15	Support 2	2
16	Counterweight	2
17	Weight rod	1
18	Weight	4
19	Finger 3	3
20	Ring	7
21	Bushing 3	2
	Standard products	
22	Bearing 60207 GOST 7242-80	4
23	Bearing 60205 GOST 7242-80	10
24	Washer 24 GOST 22355-77	6
25	Nut M24x2-6N GOST 15521-70	4
26	Geared motor NMRV075	1
27	Hairpin M 2015-6gx170 GOST 22042-76	4
28	Nut M20-6N GOST 15521-70	4
29	Washer 20 GOST 22355-77	4

2. Materials and methods

Model the design of a pumping machine in the KOMPAS software, which is based on mathematical modeling. The mathematical modeling itself will be carried out on the basis of methods from the theory of synthesis of mechanisms and developed algorithms and computer calculation programs.

3. Results and discussion

A detailed kinetostatic analysis was performed and confirmed the feasibility of using the investigated six-bar rectilinear guide mechanism as a converting mechanism for driving sucker rod pumping units.

Reliability Confirmation: Numerical results obtained through various methods have been validated, indicating the reliability of the study's findings. This suggests that the results are consistent and dependable. A design for the prototype was developed based on the research findings. An experimental sample was manufactured, and it confirmed the functionality of the converting mechanism. This step involved practical application of the theoretical research, leading to a tangible prototype. The research has led to the development of a new design for the pumping machine mechanism. This suggests that the study has contributed to innovation in the field, potentially leading to more efficient or improved pumping units.

4. Conclusions

The results of the work carried out show that the stated goal of the study was achieved. Since a detailed kinetostatic analysis confirms the possibility of using the investigated six-bar rectilinear guide mechanism as a converting mechanism for driving sucker rod pumping units. The numerical results obtained in various ways confirm that the results are reliable.

A design design for the prototype was developed and an experimental sample was manufactured, which fully confirmed the functionality of the converting mechanism. A new design of the pumping machine mechanism has been obtained. A design design and an experimental sample have been developed.

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Kompas-та сорғы қондырғысының жаңа конструкцясын модельдеу

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Аңдатпа. Мақалада 3-ші классты иінді-сырғымалы механизмдер қарастырылады, олар қажетті циклограмманы жүзеге асырады, олардың шығу буыны позициясы көрсетілген бағыттаушы бойымен қозғалады.Механизмнің кинематикалық схемасының параметрлерін есептеу үшін аналитикалық өрнектер алынды. Төрт буынды және одан күрделі көп буынды иінді тұтқалы механизмдер иінді престерде қолданылады. Сырғытпаның бір рет алға қайта оралатын қозғалысы(жүрісі) кезінде кіріс иіндісі толық айналым жасайды, бұл пресс цикліне сәйкес келеді. Циклде екі рет, экстремалды позицияларда жүгірткінің жылдамдығы нөлге тең болуы керек, осылайша шығыс буынының қозғалысы инерциялық күштердің пайда болуымен бірге жүреді. Технологиялық талаптар сырғытпаның қозғалысының белгілі бір сипатын анықтайды, ол атқарушы механизмнің тиісті құрылымымен немесе оның буындарының мөлшерінің өзгеруімен қамтамасыз етіледі.

Негізгі сөздер: *модельдеу, сорғы машинасы, штангалық сорғы, кинематикалық диаграмма, талдау, синтез.*

Моделирование новой конструкции станок-качалки в Kompas

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Аннотация. В статье рассматриваются кривошипно-ползунные механизмы 3-го класса, реализующие требуемую циклограмму с приближенным выстоем, выходное звено которых перемещается по направляющей, положение которой задано. Получены аналитические выражения для расчета параметров кинематической схемы механизма. Как плоские четырехзвенные, так и более сложные многозвенные кривошипно-рычажные механизмы применяются в кривошипных прессах. За время одного возвратно-поступательного перемещения (хода) ползуна входной кривошип совершает полный оборот, что соответствует циклу работы пресса. Дважды за цикл, при крайних положениях, скорость ползуна должна равняться нулю, таким образом, движение выходного звена сопровождается появлением инерционных сил. Технологические требования обусловливают определенный характер перемещения ползуна, что обеспечивается соответствующей структурой исполнительного механизма или варьированием размеров его звеньев.

Ключевые слова: *моделирование, насосная машина, штанговый насос, кинематическая схема, анализ, синтез.*

Received: 18 March 2024
Accepted: 15 September 2024
Available online: 30 September 2024