MACHINE SCIENCE

ISSN: 2227-6912
E-ISSN: 2790-0479

2022, Volume 11, № 1. Pages 47 – 58

THE EFFECT OF THE ROTATION DIRECTION OF CRANK ON THE KINEMATIC CHARACTERISTICS AND EXTREME FORCES OF THE RODS SUSPENSION POINT

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Abstract: In article carried out a kinematic study of a new constructive solution of pumping unit, which used in oilfield and the influence of the direction of rotation of the crank on the kinematic characteristics of the rod suspension point and extreme forces in both axial and deaxial-converting mechanisms was evaluated. Studies have shown that, according to the elementary theory, changing of direction of rotation of the crank does not affect the load on the rods suspension point, but according to the refined theory, the direction of rotation of the crank has a significant effect on the operation of the pumping unit. Because in this case, the laws of motion of the rods suspension point is sharply change. In addition, it was found that the fundamental difference between the axial and deaxial-converting mechanisms is due to the change in average speed during the up and down stroke movement of the rods suspensions point. It has been found that on pumping units with positive deaxial-converting mechanisms when the crank rotates clockwise, the rods suspension point moves upstroke faster than when it moves down, or vice versa, when the the crank rotates counterclockwise, the time at which the rods suspension point moves up is later than when it moves down. On pumping units with negative deaxial transforming mechanisms when the crank rotates clockwise, upstroke time of rods suspension point is less than it is downstroke time. And on pumping units with negative deaxial transforming mechanisms when the crank rotates clockwise, the upstroke time of the rods suspension point is longer than when it moves down and vice versa, when the crank rotates counterclockwise, the upstroke time of the rods suspension point is less than when it moves down.

Key words: *pumping unit, axial, deaxial, rods, block, crank*

Introduction. One of the most important places in the economic development of the Republic of Azerbaijan takes the extraction and transportation of oil to world markets. It is no coincidence that in the former Soviet Union, the research institutes of Azerbaijan were the leaders in the design and production of pumping units used in oil extraction. The mechanical transmissions of the sucker-rod pumps designed by these research institutes, as well as the pumping units and reducers used in these mechanical transmissions were considered as standards. Therefore, in the modern stages of oil science, the creation of a new design of pumping units with a more advanced transmission mechanism, which saves electricity, reduces overall dimensions, increases longevity and efficiency, is relevant and have great practical importance for the mechanical transmission of pumping units.

It is known that the most common equipment used in mechanized oil production is a sucker-rod well pumping unit. These equipment consist of an individual well pump, which is lowered into the well with rods to the under dynamic level of the liquid, a pumping unit, its transmission and converting mechanisms. The plunger of downhole pump is actuated by the pumping unit. During the upstroke and downstroke movement of the plunger, the operation of the downhole pumps is observed by changing the direction of movement of the rod column [1-5].

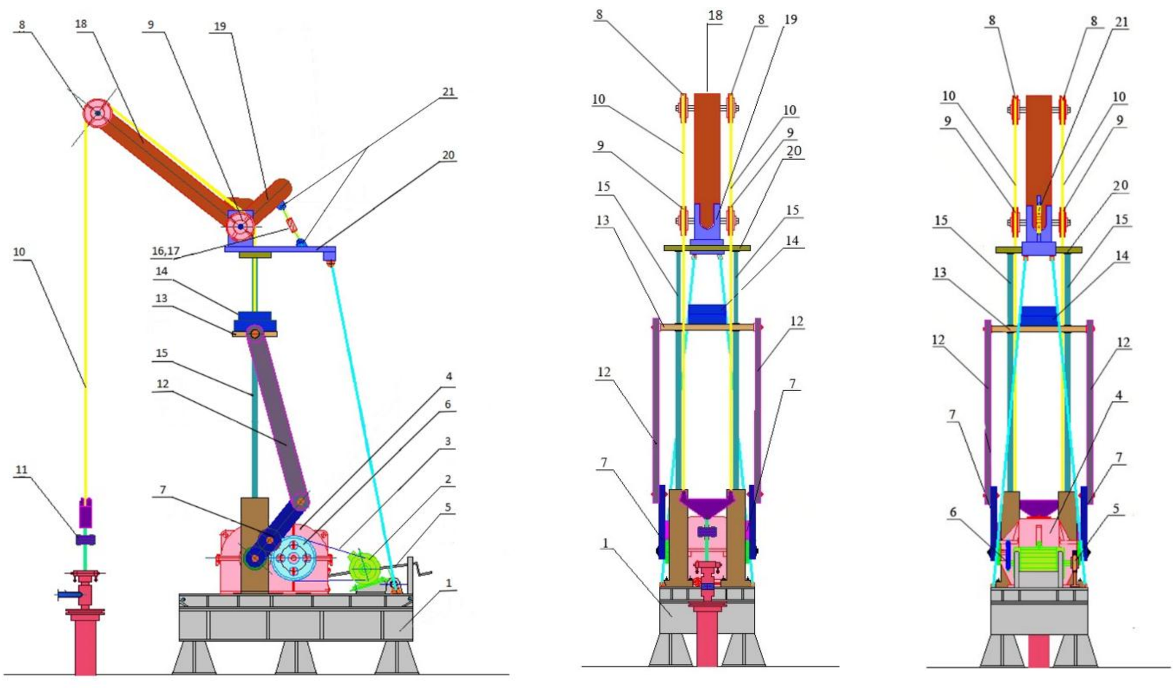
Given the large number of these pumping units in operation, one of the urgent issues is to improve them and create new designs with a more perfect design. For this purpose at the Department of "Mechatronics and Machine Design" of Azerbaijan Technical University, was developed an original constructive solution of mechanical drive of the pumping unit, which provides both stable operation and energy saving, as well as a reduction in overall dimensions and an increase in reliability. The originality of the new equipment was confirmed by the patent of the

Intellectual Property Agency of the Republic of Azerbaijan (patent № İ 2021 0113) and the patent of the Eurasian Patent Organization (patent № 039650) [6,7].

At Figure 1 shown the overview of the new constructive solution of the sucker-rod pumping unit. The new constructive solution of the sucker-rod pumping unit consist from frame (1), three-phase short-circuited asynchronous motor (2), V-belt drive (3), rigidly connected two-flow three-stage reducer (4), on the drive shaft of which on one side mounted double-shaped brake (5) and on the other side V-belt pulley (6), and on the driven shaft of its installed two cranks (7); guide blocks (8, 9), ropes (10) connected to the rods suspension point.

The converting mechanism, which consists of two slider-crank linkage (12), converts the rotational motion of the crank into the upstroke and downstroke movement of the rod suspension point. The mechanical transmission has counterweights whose weight can be adjusted (14), located on a movable cross beam (13), which is connected with hinge joint to the connecting-rod.

The guide blocks are surrounded by a flexible rope, one end of which is connected to the movable beam, and the other end is connected to the rods suspension point. In addition, the mechanical drive has a guide system consisting of two vertically located cylindrical tubes (15) and the movable beam. The mechanical transmission has articulated front (18) and rear (19) arms, which can be adjusted by using (16,17) screw tensioners, a fixed cross beam (20) rigidly connected to the guide tubes. The screw tensioner (21) is connected to the frame of the construction, as well as to the joints with the front and rear arms.



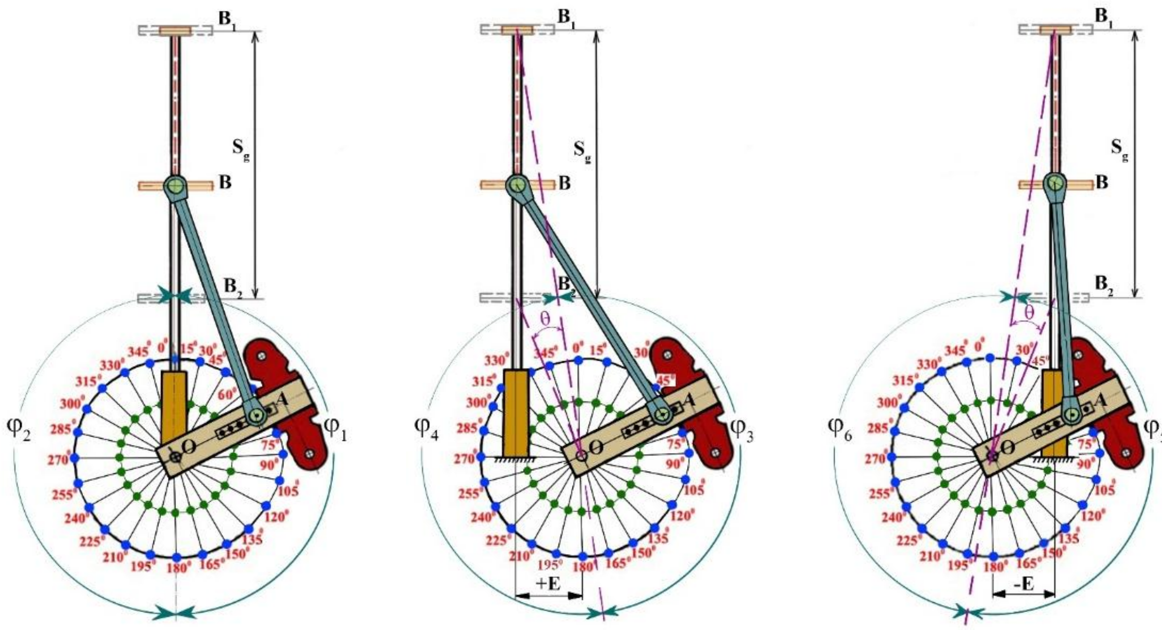
a) *b)* *c)*

Figure 1. New constructive solution of beamless pumping unit consisting of an slider-crank mechanism and a rope-block system:
a - side view; b - front view; c - rear view

The converting mechanism is used on the pumping unit to ensure the upstroke and downstroke movement of the rods column. Currently, the four-link hinged slider-crank linkage mechanism is used in the converting mechanisms of the pinches. It is known that the purpose of kinematic analysis of each hinged mechanism is to determine the displacement, velocity and acceleration of its corresponding points.

Formulation and solution of the problem. The kinematic characteristics of the rods suspension point, i.e. the stroke of the rods suspension point, its speed, and the acceleration change during a complete cycle of the pumping unit crank. Therefore, the laws of motion of the rods suspension point depend on the kinematic scheme of the adopted transforming mechanism. Depending on the type of transforming mechanism, the mechanical transmissions of the sucker-rod pumps can be divided into two types, namely, beam and beamless pumping units. In the first case, the upstroke and downstroke movement of the rods column is achieved by using the slider-crank mechanism with beam. In the slider-crank mechanism of a beam pumping unit, the lengths of the links may be constant or vary in length during one cycle of the pumping units transmission. In beamless pumping units, the upstroke and downstroke movement of the rods column is achieved by a flexible element (rope or chain) applied to the transforming mechanism.

The location of the crank on the transforming mechanism of the pumping unit is very important (Figure 2). This location significantly affects the operating parameters of the downhole pump.



a) *b)* *c)*

Figure 2. Scheme of the transforming mechanism of the pumping unit for three different positions of the crank

In the transforming mechanism of the proposed innovative construction, the location point of the crank can be in three different variants.

If the center of the elbow is located on the straight line B_1-B_2, then such a mechanism is called a centrally symmetric axial mechanism. If the center of the crank is located to the right or left of the straight line B_1-B_2, then this mechanism is called an asymmetric mixed (daxial) mechanism.

Deaxial slider-crank mechanism itself can be positive (O_1A_1BCD) and negative (O_2A_2BCD) deaxial. The main difference between the slider-crank mechanisms is the change in the average speed during the up and down stroke movement of the rods suspension point.

Indeed, if the mechanism is axial (OABCD), during the displacement of the horse head from the lower edge position (B2) to the upper edge position (B1), the crank will rotate by an angle φ_1 in the direction of the clockwise movement (oil well head is on the left side). If vice versa, i.e., will rotate by an angle φ_2 during the horse head displacement from the upper edge position (B_1) to the lower edge position (B_2). In this case, since the mechanism is an axial mechanism, $\varphi_1 = \varphi_2 = 180^0$. Therefore, regardless of the direction of rotation of the crank, the time for both up and down stroke movement of the rods suspension point is the same (photo 2, a).

If the mechanism is positive deaxial (O_1A_1BDC), then during of the upstroke movement of the rods suspension point, the crank will rotate in the direction of clockwise movement (oil well head is on the left side) by an angle φ_3, and during its downstroke movement by an angle φ_4. As can be seen from Figure 2, b, the angle φ_3 is smaller than the angle φ_4, so the time for the up stroke movement of the rods suspension point is faster than the time for it to down stroke movement or vice versa, and when the crank rotates in the opposite direction of clockwise movement the rods suspension point moves up stroke movement time is later than the time of its downstroke movement.

If the mechanism is negative deaxial (O_2A_2BCD), then during of the up stroke movement of the rods suspension point, the crank will rotate in the direction of clockwise movement (oil well head is on the left side) by an angle φ_5, and during down stroke movement by an angle of φ_6. As can be seen from Figure 2, c, the angle φ_5 is greater than the angle φ_6, so the time when the rods suspension point of the moves up is later than the time when it moves down, or vice versa, when the crank rotates in the opposite direction of the clockwise movement, the upstroke movement time of the rods suspension point is faster than the time it moves down.

In mining practice, the direction of rotation of the crank is usually assumed to be clockwise in both axial and deaxial pumping units. Such a choice of the direction of rotation of the crank has a great importance. Because even in axial (symmetrical) pumping units, the laws of movement of the rods suspension point are unsymmetrical.

According to the existing research methods, three main theories are applied, i.e. elementary, refined and exact theory, based on the degree of simplification and accepted assumptions when studying the laws of movement of the suspension point.

It is always possible to accurately determine the displacement of the rods suspension point, its speed and acceleration. In this case, the studied transforming mechanism is considered as a closed geometric figure in all cases. Such a figure has enough dimensions to find its angles and sides. However, it should be noted that even for simple mechanisms, the equations obtained by the exact method are so complex that their practical use for engineering calculations causes great difficulties. Therefore, elementary and refined theories are used more often when conducting kinematic research of transforming mechanisms in oil field practice (table 1) [8-15].

Table 1. Formulas to finding of kinematic characteristics of sucker-rod pumps with axial and deaxial mechanisms

For axial mechanisms		
Kinematic characteristics	Elementary method	Refined method
movement	$S_B = r(1 - cos\varphi)$	$S_B = r\left(1 - cos\varphi + \frac{1}{2} \cdot \lambda^2 sin^2\varphi\right)$
speed	$V_B = \frac{ds}{dt} = \omega \cdot r \cdot sin\varphi$	$V_B = \frac{ds}{dt} = \omega \cdot r \cdot \left(sin\varphi + \frac{\lambda}{2} sin2\varphi\right)$
acceleration	$a_B = \frac{dV_B}{dt} = \omega^2 \cdot r \cdot cos\varphi$	$a_B = \omega^2 \cdot r \cdot \left(cos\varphi + \frac{\lambda}{2} cos2\varphi\right)$
For deaxial mechanisms		
Kinematic characteristics	Elementary method	Refined method
movement	$S_B = r\left[\sqrt{\left(\frac{1}{\lambda} + 1\right)^2 - \varepsilon^2} - \frac{1}{\lambda} - cos\varphi\right]$	$S_B = r\left[1 - cos\varphi + \frac{\lambda}{4}(1 - cos2\varphi) + \varepsilon\lambda sin\varphi - \frac{\varepsilon^2\lambda^2}{2(\lambda+1)} + \frac{\lambda\varepsilon^2}{2}\right]$
speed	$V_B = \frac{ds}{dt} = \omega \cdot r \cdot sin\varphi$	$V_B = \omega \cdot r \cdot \left[sin\varphi + \frac{\lambda}{2} sin2\varphi + \varepsilon\lambda cos\varphi\right]$
acceleration	$a_B = \frac{dV_B}{dt} = \omega^2 \cdot r \cdot cos\varphi$	$a_B = r\omega^2 \cdot [cos\varphi + \lambda cos2\varphi - \varepsilon\lambda sin\varphi]$

In order to evaluate the influence of the direction of rotation of the crank on the extreme forces at the rods suspension point, the kinematic characteristics of axial pumping unit model of СК-6-2,1-2500 and the deaxial pumping unit model of СКД6-2,5-2800 ($r = 1000\,mm, l = 2500\,mm$, E=1500 mm) for different values of the relative length factor (λ) and relative eccentricity (ε) respectively, the displacement of the rods suspension point, its speed and acceleration were determined based on both elementary and refined theories [16-20].

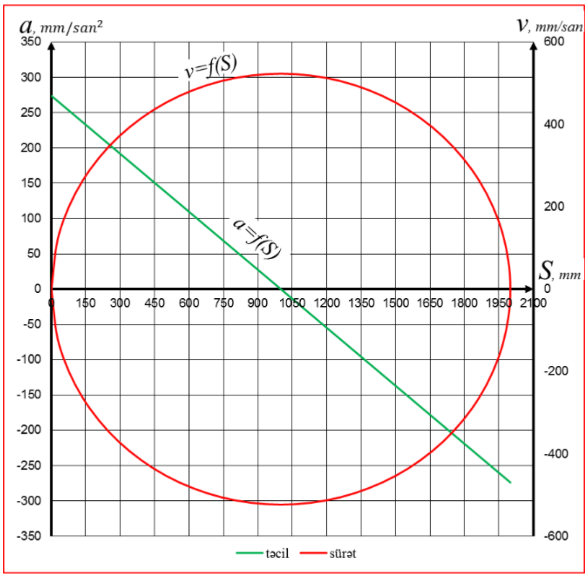
Table 2. Results of calculations for constructing graphs of functions $S = f(\varphi), v = f(\varphi)$ and $a = f(\varphi)$.

Angel φ, degree	Elementary method			Refined method		
	S, m	*v*, m/sec	*a*, m/sec^2	*S*, m	*v*, m/sec	*a*, m/sec^2
0	0	0	175	0	0	245
15	34,	108	169	47	150	230
30	134	209	152	184	282	187
45	293	296	124	393	380	124
60	500	362	88	650	435	53
75	741	404	45	928	446	-15
90	1000	419	0	1200	419	-70
105	1259	404	-45	1445	363	-106
120	1500	36	-88	1650	290	-123
135	1707	296	-124	1807	212	-124
150	1866	209	-152	1916	137	-117
165	1966	108	-169	1979	67	-109
180	2000	0	-175	2000	0	-105
195	1966	-108	-169	1979	-67	-109
210	1866	-209	-152	1916	-137	-117
225	1707	-296	-124	1807	-212	-124
240	1500	-362	-88	1650	-290	-123
255	1259	-404	-45	1445	-363	-106
270	1000	-419	0	1200	-419	-70
285	741	-404	45	928	-446	-15
300	500	-362	88	650	-435	53
315	293	-296	124	393	-380	124
330	134	-209	152	184	-282	187
345	34	-108	169	47	-150	230
360	0	0	175	0	0	245

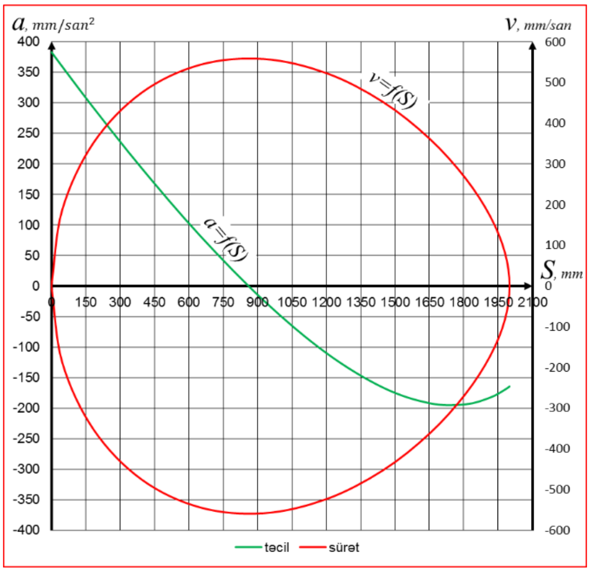
Table 2 shows the results of calculations for constructing graphs of functions $S = f(\varphi), v = f(\varphi)$ and $a = f(\varphi)$. The speed and acceleration of the rods suspension point was performed for the case of the number of swings $n = 5\,min^{-1}$. Showing speed and acceleration on the graphs in this form shows more clearly the influence of the direction of rotation of the crank on the loading of the rods suspension point.

As can be seen from Graph 1, changing the direction of rotation of the crank does not affect the loading of the rod suspension point. Because the change of speed depending on the displacement of the rods suspension point occurs on a circle, and the change of acceleration occurs according to the straight line law.

As can be seen from the Graph 2, in reality, the direction of rotation of the crank has a significant influence on the working mode of the pumping unit. As can be seen from the graphs, the regularities of movement of the rods suspension point on these pumping unit are also drastically different from each other.



Graph 1. Graphs of the dependence of the speed and acceleration of the axial transforming mechanism on the displacement of the rods suspension point according to the elementary theory



Graph 2. Graphs of the dependence of the speed and acceleration of the axial transforming mechanism on the displacement of the rods suspension point according to the refined theory

Indeed, during the clockwise rotation of the crank while the rods suspension point is moving upwards (oil well head is on the left side), its velocity corresponds to the OAO_1 curve, and the acceleration to the CBC_1 curve. During counterclockwise rotation of the crank (oil well head is on the left side), the speed of the rod suspension point corresponds to the curve OA_1O_1, and the curve CBC_1 corresponds to its acceleration. Let's assume that the combined deformation of the pipes lowered into the well and the rods column of the pumping unit being studied is $\lambda^* = 380\ mm$. Then, during the clockwise rotation of the crank, the displacement of the rod suspension point will correspond to the speed value of $380\ mm/sec$, and the acceleration value to $260\ mm/sec^2$. When the crank rotates in the counter-clockwise direction, the value of the speed will be $340\ mm/sec$, and the acceleration will be $365\ mm/sec^2$.

A comparison of these cases shows that it is more convenient to take the direction of rotation of the crank in the direction of clockwise rotation for pumping unit with an axial converter mechanism. Because in this case, the absolute values of the speed and acceleration decrease at the moment of recovery of the deformations of the pipes and rods during the upward movement. Reducing the absolute values of the speed and momentum at the time of recovery of the deformations of the pipes and rods leads to a reduction of the dynamic forces acting on the sucker-rod pumping unit [21-26].

According to the formulas proposed in table 1, the displacement of the rods suspension point, its speed and acceleration according to the kinematic characteristics of the deaxial pumping unit model of СКД6-2,5-2800 were calculated based on both elementary and refined theories, and the calculation results are shown in table 4.

Calculations were performed for both negative and positive deaxial converter mechanisms. In order to more conveniently analyze the studied kinematic schemes, they are conditionally divided into 4 schemes (table 3):

Scheme 1 – this scheme is a negative deaxial kinematic scheme, the direction of rotation of the crank is clockwise;

Scheme 2 – this scheme is a negative deaxial kinematic scheme, the direction of rotation of the crank is counter-clockwise;

Scheme 3 – this scheme is a positive deaxial kinematic scheme, the direction of rotation of the crank is clockwise;

Scheme 4 – this scheme is a positive deaxial kinematic scheme, the direction of rotation of the crank is counterclockwise.

Table 3. diferent variants of schemes by type of converting mechanism

Variants	Type of converting mechanism	*r*, mm	λ	ε
	Axial	1000	0,4	-
1,2	Negative deaxial	1000	0,4	+1,5
3,4	Positive deaxial	1000	0,4	-1,5

On the basis of the conducted studies, it was determined that during the rotation of the crank in the direction of clockwise motion, the largest value of the displacement of the rods suspension point during the upstroke movement in the pumping unit with positive deaxial converter mechanism is less time compared to the axial converter mechanism, and in the case of the negative deaxial converter mechanism more time is achieved (table 4).

During clockwise rotation of the crank, increasing the positive deaxial distance in the positive direction, its maximum value increases during upward movement of the rods suspension point, and decreases during downward movement. When the deaxial distance is increased in the negative direction, the maximum speed of the rod suspension point decreases during the upward movement, and increases during the downward movement.

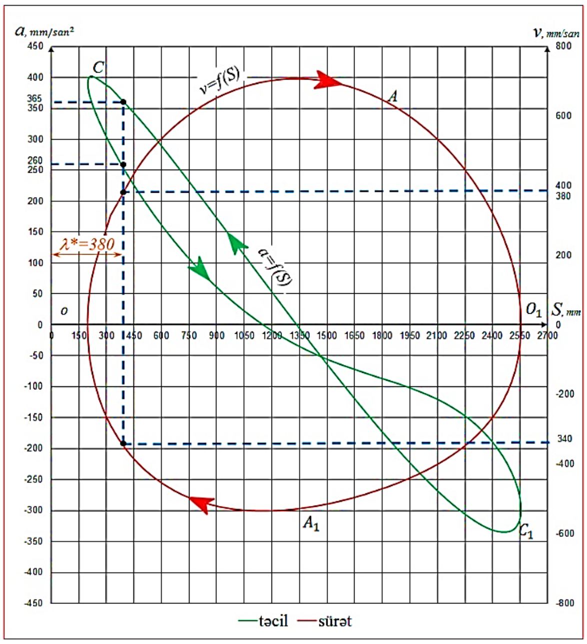
Table 4. Results of calculations of kinematic characteristics of sucker-rod pumps by elementary and refined methods

Angle, φ	Elementary method						Refined method					
	Positive deaxial			Negative deaxial			Positive deaxial			Negative deaxial		
	S, m	*v*, m/sec	*a*, m/sec^2	*S*, m	*v*, m/sec	*a*, m/sec^2	*S*, m	*v*, m/sec	*a*, m/sec^2	*S*, m	*v*, m/sec	*a*, m/sec^2
0	-337	0	274	-337	0	274	321	314	383	321	-314	383
15	-303	135	264	-303	135	264	524	491	317	213	-115	402
30	-203	261	237	-203	261	237	805	624	210	205	80	374
45	-44	370	193	-44	370	193	1138	697	77	290	253	310
60	162	453	137	16	453	137	1491	701	-60	451	3867	224
75	403	505	71	403	505	71	1828	639	-182	670	476	135
90	662	523	0	662	523	0	2121	523	-274	921	523	55
105	921	505	-71	921	505	-71	2346	372	-324	1187	534	-7
120	1162	453	-137	1162	453	-137	2491	205	-334	1451	519	-49
135	1369	370	-194	1369	370	-194	2553	43	-310	1704	487	-77
150	1528	261	-237	1528	261	-237	2537	-101	-264	1937	443	-100
165	1628	135	-264	1628	135	-264	2456	-220	-212	2145	386	-127
180	1662	0	-274	1662	0	-274	2321	-314	-164	2321	314	-164
195	1628	-135	-264	1628	-135	-264	2145	-386	-127	2456	220	-212
210	1528	-261	-237	1528	-261	-237	1937	-443	-100	2537	101	-264
225	1369	-370	-194	1369	-370	-194	1704	-487	-77	2553	-43	-310
240	1162	-453	-137	1162	-453	-137	1451	-519	-49	2491	-205	-334
255	921	-505	-71	921	-505	-71	1187	-534	-7	2346	-372	-324
270	662	-523	0	662	-523	0	921	-523	55	2121	-523	-274
285	403	-505	71	403	-505	71	670	-476	135	1828	-639	-182
300	162	-453	137	162	-453	137	451	-387	224	1491	-701	-60
315	-44	-370	194	-44	-370	194	290	-253	310	1138	-697	77
330	-203	-261	237	-203	-261	237	205	-80	374	805	-624	210
345	-303	-135	264	-303	-135	264	213	115	402	524	-491	317
360	-337	0	274	-337	0	274	321	314	383	321	-314	383

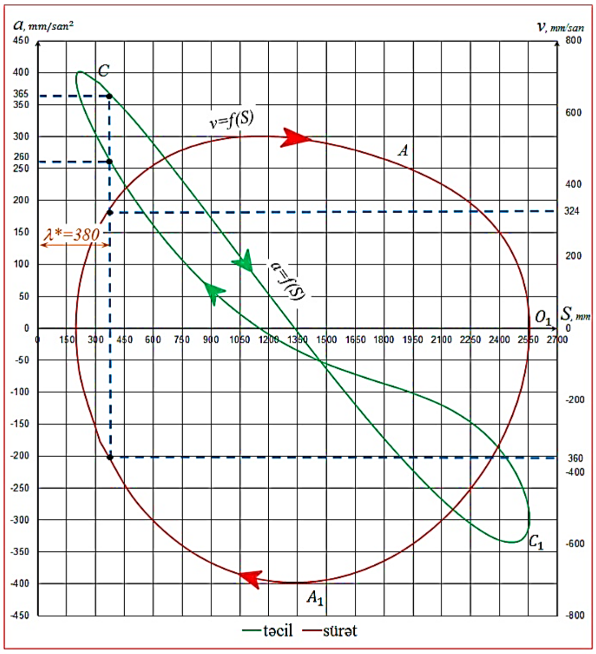
As a result of the comparative analysis carried out in this way, we determine that the reduction of the time for the upward movement of the rods suspension point o can be achieved by two methods. For this purpose, it is recommended to use either sucker-rod pumping units with a positive deaxial transformin mechanism when the crank rotates in the clockwise direction, or with a negative deaxial translation mechanism when the crank rotates in the opposite direction of the clockwise direction of movement (table 5).

Table 5. The result of the comparative analysis

Variant of the scheme	Deaxial character	The direction of rotation of the crank	speed, m/sec	acceleration, m/sec^2	The travel time of the rods suspension point	
					Upstroke, sec	Downstroke, sec
1	Negative	Clockwise movement	0,325	0,199	7,85	5,54
2	Negative	Counter-clockwise movement	0,461	0,247	5,54	7,85
3	Positive	Clockwise movement	0,461	0,247	5,54	7,85
4	Positive	Counter-clockwise movement	0,325	0,199	7,85	5,54



Graph 3. Graphs of the dependence of the speed and acceleration of the rods suspension point from its movement on a positive deaxial pumping unit (according to the refined theory)



Graph 4. Graphs of the dependence of the speed and acceleration of the rods suspension point from its movement on a negative deaxial pumping unit (according to the refined theory)

Based on the conducted research, it was determined that increasing the average speed of the rods suspension point during the upstroke movement reduces the time of its upstroke movement. On the other hand, reducing the time of upstroke movement of the plunger pump also reduces the absolute cost of backflow of the pumped liquid between the plunger and the cylinder, which leads to an increase in its productivity. Therefore, in order to determine the degree of influence of the axial on the efficiency of the pumping unit, it is of great importance to quantify the effect of the size of the axial of the crankcase on the upstroke movement time of the rod suspension point (table 5).

If the crank rotates with a constant angular velocity, then the ratio of the angles of rotation will be as follows:

$$\frac{\varphi_1}{\varphi_2} = \frac{t_1}{t_2}$$

where t_1 and t_2 - are the times of up and down stroke of the rods suspension point, respectively.

Since the times t_1 and t_2 are known in the application, depending on the movement taken by the rods suspension point, the speeds during its upstroke and downstroke movement are known, then

$$\frac{v_1}{v_2} = \frac{t_2}{t_1} = \frac{\varphi_2}{\varphi_1} = K_0$$

burada K_0 – is the coefficient of change of the average speed of the rods suspension point. The value of this coefficient is usually determined depending on the change of the deaxial angle during the up and down movement of the suspension point of the bar:

$$K_0 = \frac{180^0 + \theta}{180^0 - \theta}$$

If the times of upstroke and downstroke movement of the rods suspension point are equal $\theta = 0$. That is, in this case, since the transforming mechanism is axial, $\varphi_1 = \varphi_2$.

And for deaxial mechanisms

$$\theta = arcsin\frac{E}{l+r} - arcsin\frac{E}{l-r} = arcsin\frac{\varepsilon\lambda}{(1+\lambda)} - arcsin\frac{\varepsilon\lambda}{(1-\lambda)} = arcsin\frac{-2\varepsilon\lambda^2}{(1-\lambda^2)}$$

This formula of the coefficient of variation of the average speed allows to determine the dependence $K_0 = f(E)$. Table 5 shows the initial data for establishing the proposed dependency at different line light of the movement for the known length of the connecting rod ($l = 2800\ mm$) for deaxial pumping unit model of СКД6-2,5-2800.

Based on the results of the calculation, the table shows how much time it takes for the rods suspension point to move up and to down by moving the reducer to the right or to the left from the position that ensures the symmetry of the crank-slide mechanism at different values of λ and ε in the specific upstroke movement of the rod suspension point on this pumping unit allows us to determine what is different (table 6).

Table 6. The time of movement up and down of rods suspension depending on different values of λ and ε

relative eccentricity ε	Coefficient of variation of the average speed of the pumping unit			
	λ=0.1	λ=0.2	λ=0.3	λ=0.4
-2	1,02606	1,112603	1,297437	1,761422
-1,75	1,02277	1,097725	1,253553	1,605115
-1,5	1,01948	1,083101	1,212113	1,480191
-1,25	1,01621	1,068718	1,172798	1,375248
-1	1,01295	1,054562	1,135339	1,284158
-0,75	1,00969	1,040623	1,09951	1,203203
-0,5	1,00645	1,02689	1,065119	1,129933
0	1	1	1	1
0,5	0,99359	0,973814	0,938862	0,885008
0,75	0,9904	0,960962	0,909496	0,831115
1	0,98722	0,948261	0,880795	0,77872
1,25	0,98405	0,935701	0,852662	0,727141
1,5	0,98089	0,923275	0,825005	0,675588
1,75	0,97774	0,910975	0,797733	0,623008
2	0,9746	0,898794	0,77075	0,567723

For clarity, let's quantify how much the absolute value of leaks decreases when the time of the rod suspension point moves up, depending on the parameters adopted according to the specific well conditions. For this, let's assume that the number of oscillations of the rods suspension point of the pumping unit per minute is $n = 5\ min^{-1}$. Then, the total time for upstroke and downstroke movement of the rods suspension point (in one complete cycle of the crank) will be 13,39 seconds. For axial mechanisms, this time will be evenly distributed, that is, it will take 6,695 seconds to move both up and down. If we take the relative length coefficient as $\lambda = 0{,}4$ and the deaxial angle $\theta = 25^0$, then $K_0 = 1{,}322$ will correspond to this angle and $\frac{t_H}{t} = 1{,}322$. This time ratio can be provided in two ways:

1) In the tranforming mechanism of the pumping unit, assuming the case of rotation of the crank in the counter-clockwise direction, taking the relative deaxiality $\varepsilon = -1{,}107$;

2) In the tranforming mechanism of the pumping unit, taking the relative deaxiality $\varepsilon = +1{,}107$ and assuming the case of rotation of the crank in the clockwise direction.

Results and conclusions. The kinematic study of the new constructive solution of pumping unit was carried out, and the effect of the direction of rotation of the crank on the kinematic characteristics of the rods suspension point and extreme forces in the axial and deaxial converter mechanisms was evaluated. Studies have shown that, according to the elementary theory, changing of direction of rotation of the crank does not affect the load on the rods suspension point, but according to the refined theory, the direction of rotation of the crank has a significant effect on the operation of the pumping unit, because in this case, the laws of motion of the rods suspension point is sharply change.

According to the kinematic characteristics of the pumping unit model of СКД6-2,5-280, was calculated and numerically determined the average speed change during the upward and downward movement of the bar suspension point of the new beamless pumping unit with axial and deaxial transforming mechanism. It has been found that on pumping units with positive deaxial transforming mechanisms when the crank rotates clockwise, the rods suspension point moves upstroke faster than when it moves down, or vice versa, when the crank rotates counterclockwise, is later than when it moves down. On pumping units with negative deaxial transforming mechanisms with negative deaxial-converting mechanisms when the crank rotates clockwise, upstroke time of rods suspension point is less than it is downstroke time. However, on pumping units with negative deaxial transforming mechanisms when the crank rotates clockwise, the upstroke time of the rods suspension point is longer than it is downstroke time and vice versa, when the crank rotates counterclockwise, the upstroke time is less than when it moves down. Based on the comparative analysis, in order to reduce the losses caused by leaks in the liquid lifted by the plunger and to increase the actual productivity, it is possible to reduce the time of the suspension point of the pumping unit to move up in two ways. For this purpose, it is recommended to use either sucker-rod pumping units with a positive deaxial transforming mechanism when the crank rotates in the clockwise direction, or with a negative deaxial translation mechanism when the crank rotates in the opposite direction of the clockwise direction of movement.

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Received: 29.03.2022
Accepted: 12.05.2022