Grab Bucet with straight linear progressive movement of jaws

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ABSTRACT: special rowing up grab buckets are used in construction for performing clearing, loading and unloading functions; when mining thin layers of soil and basic materials. The efficiency of grab buckets with large opening of the jaws can be sufficiently increased by providing straight linear progressive movement of the jaws when the angle of shearing doesn't change. The constructed control algorithms allow to detour the obstacles, move in straight and curve trajectories with the specified speed, to decrease the rate of construction's movement, to perform orientation of construction and provide its smooth installation into the projective position.

KEYWORDS: excavating machines, construction, grab working, kinematic scheme, control algorithms, visual sensor, mobile robots, planning of the robot's movement, kinematics.

1. INTRODUCTION

Grab working parts of excavating machines are known to be the types of a most effective equipment available. Special rowing up grab buckets are used in construction for performing clearing, loading and unloading functions; when mining thin layers of soil and basic materials. They are characterized by large opening of the jaws with the sloping path of motion and slight intrusion into the soil. The deficiency of grab buckets is the variability of the shearing angle of the cutting crimps in the process of closing the jaws that reduces the efficiency of mining.

The efficiency of grab buckets with large opening of the jaws can be sufficiently increased by providing straight linear progressive movement of the jaws when the angle of shearing doesn't change. This result was achieved due to the synthesis of a compact flat lever mechanism with progressive section suitable for using in the kinematic scheme of grab buckets of special function.

2. THEORY AND EXPERIMENT

The basis of the synthesis is simple and compact Evince mechanism connected with supplemental sections which resulted in developing the curve tongue movable straight linear directing mechanism with the section moving in the straight linear translation way.

The structural scheme of the mechanism is given in figure I: foundation 1 with a straight-line directing mechanism 2, crank 3 positioned in the directing mechanism 2, slide 4 twice as long as the crank and connected with the end to slide 4 by means of common joint D, the

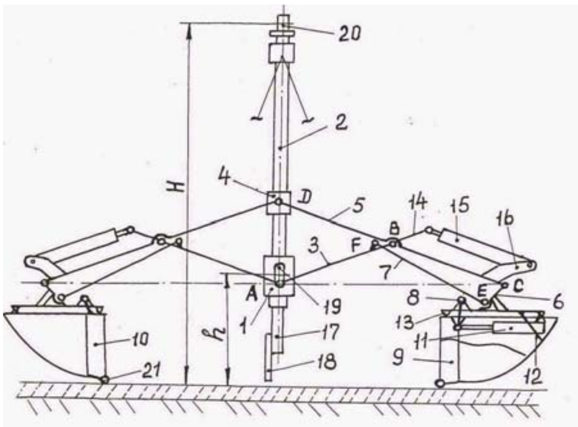

Figure 1. The structural scheme of the mechanism

central part being connected with crank 3 by means of joint B. The other end of connecting rod 5 is joined to the connecting rod 6 the other end of which is joined to the end of the third connecting rod 7. The other end of connecting rod 7 by means of joint F is kinematically connected with crank 3. Joint F is positioned eccentrically to crank shaft on section 8 strongly linked with the crank. Joint A of crank 3 is placed on the .shaft of directing mechanism 2.

When turning crank 3 in position of angle G slide 4 moves along directing . (mechanism) 2 and joint C, according to the principle of action of Evince mechanism moves along shaft X. Parallelly four sectioned joint BCEF provides straight linear progressive movement of connecting rod 6, i.e. constancy of its position in angle L to shaft X, that can only be attained with the definite relation of geometrical parameters of the mechanism.

To prove this let's accept in dimensionless form the length of the second connecting 6 which is equal to *l*, the length of the third connecting rod 7 is equal to B, the distance between joints B and F is equal to τ and lengths of sections AB=BC=BD=I. The distance τ and angle β between the shaft of crank 3 and straight-lin connecting joints B and F determines eccentricity of joint F in relation to crank 3.

In this case the current meanings of abscissa and ordinate of points E and F will accordingly be equal to

$$x_E = 2\sin\varphi - l\cos\alpha,$$

$$x_F = \sin\varphi - \tau\sin(\varphi+\beta), \qquad (1)$$

$$y_E = l\sin\alpha,\ y_F = \cos\varphi - \tau\cos(\varphi+\beta.) \qquad (2)$$

If intermediate values $m = \sin\varphi + \tau\sin(\varphi+\beta)$ and $n = m^2 + y_F^2 + l^2 - B^2$, are assigned to the given equation then the current value of angle α which follows from relation $b^2 = (X_E - X_F)^2 + (Y_F + Y_E)^2$ will be defined by the following expression

$$\alpha = \arcsin\left(\frac{Y_F + \sqrt{n^2Y_F^2 - \left(Y_F^2 + m^2\right)\left(n^2 - m^2l^2\right)}}{2l\left(Y_F^2 + m^2\right)}\right)^{-n}$$

A straight linear progressive movement of the second connecting rod 5 is ensured if in a given diapason of the angle φ^1 of a crank turning the main condition of synthesis is observed where $l = const.$ Only definite values of outlet parameters l_1, b, τ, β correspond to it. They may 6e defined as a result of optimum synthesis of mechanism which can be described as follows.

Mathematical expression of the main synthesis condition may be defined as a purpose function

$$\Delta l = l\max - l\min \to \xi \qquad (3)$$

where *l*max, *l*min are minimum and maximum values of the angle *l*,

defined (2) in a given angle diapason of a crank turning 3:

ξ – possible change of angle *l*.

If additional synthesis conditions are expressed through limits on parameters *l*, *b*, τ and β as inequality they establish possible ways of existing mechanism construction of intervals of uncertainty

$$l_1 \le l \le l_2$$

$$b_1 \le b \le b_2$$

$$\tau_1 \le \tau \le \tau_2$$

$$\beta_1 \le \beta \le \beta_2, \qquad (4)$$

so in this case synthesis of mechanism may be brought up to parametrical optimum by nonlinear programming of a purpose function (3). The extreme value of the function defines optimum parameter values. Quotient derivatives of a purpose function in synthesis parameters can't be defined (obtained). So the procedure of its minimization may be fulfilled in algorithm of a, definite directed search through the use of a golden section method for intervals- of uncertainty (4) with the help of a computer (3).

In an elaborated mechanism the link 6 is used for attachment of working details to it which should be transmitted straight linear progressive movement, so the length *l* of the link should reasonably be chosen in a constructive way. Taking into account all that, a search of such parameter values *b*, τ, β and *l* was done on a purpose function (3) and in this case Δl was minimum. All obtained results of synthesis of such mechanism can, be shown on the diagram (2) reflecting changeability of angle l with a relative length of the link 6 that is equal to l = 0,15. As it is shown on the diagram in a wide angle diapason of a turning crank 3 is from 10° to 80° where changeability of the angle l is relevant to its average value $l_{b,}$ =46,5^{o}. It does not exceed 23°. This fact proves that a mechanism with a link moving in a straight linear direction is obtained as a result of synthesis of mechanism. The results of obtained mechanism were used in development of a grab with a large opening possibilities and straight linear progressive movement of a jaw (4). The grab shown in the picture 3 has a frame 1, that is a base of a symmetric crank of a sliding mechanism (2). Extension construction of a frame is served as a guide of mechanism. The links of mechanism are shaped as pivot farms. The grab mechanism connecting rods 5, the second connecting rods 6 and the third connecting rods 7.

The jaws (9, 10) are closely connected with the second connecting rods and joint.

The grab is furnished with two pairs of hydrocylinders for opening and apart movement of jaws.

The bodies of hydrocylmder for opening 11 are connected with joints 6 and their rods are connected with jaws 9 and 10. Refinements 12 and limits of jaw turning 13 are connected to the second connecting rods 6 and to the rods of a part movement hydrocylinder 15 are connected with durational pivots 14 cranks 3. The bodies of the rods are attached by brackets 16 to the bottom sides of connecting rods.The rack 17 with the cress reactor plate 18 is attached to the frame I in the bottom part which length is less than the width of the jaws.

The frame is supplied with the bottom grab 19 and the top ones 20 for hanging on the basic machine in various variants on the height h and H through the intermediate extension piece. The jaws are provided with the supporting rollers 21 by cleaning the surfaces with the firm covering [5].

The work of the grab is carried out as follows. The grab with the open jaws falls on the developed soil. Under effect of the rods of the hydrocylinders 15 on the cores - extension pieces 14 the curve thorns 3 rotate around the axis A, the shakers 5 and 7 make a complex movement and the four linker BCEF of the mechanism of the grab transmits a rectilinear-forward movement of the 'parts 6 together with the highly attached to them jaws 9 and 10 developing the soil. The put forward rods of the hydrocylinders 11 rest the jaws against the terminators 13 and also keep them from disclosing by the development of the soil. At the uploading place by drawing in the rods of the hydrocylinders 11 the jaws are open and the udmovable cleaners push out the soil or some other material and clean the jaws. The jaws are moved apart by drawing in the rods of the hydrocylinders 15.

When falling the grab with the open jaws on the developed soil the rack 17 with the cross plate 18 take root into the layer of the soil and by closing of the jaws resist to the displacement of the frame I to the jaw's side with the large effort of interaction with the soil at the expense of the soil shift by the cross plate to the same side. As the reaction as a result of the shift of the soil is summarized with cutting efforts of the jaw for which they are having a less meaning, an essential indemnification of the non-uniformity of the reaction of interaction between the left and the right jaw with the soil is automatically provided.

The theoretical researches were tested in the laboratory conditions on the model sample of the grab. The following initial data for the development of the grab were accepted: The capture at the complete moving apart and disclosing of the jaws - not less than 3 meters, the length of the curve horn - 90 mm the comer of the turn of the curve horns from 15 up to 75°; the relative length of lie forward link CE = 0,15 that corresponds to the absolute meaning of 135 mm at the given length of the curve thorn, the height of the jaw of 450 mm.

Taking into consideration the original data, the optimization synthesis of mechanism of clamshell was performed by a target function (3), in the result of which was gained the following values of its parameters of crank turning angle at the range of 10° to 80° : The length of the third connecting rod, the distance between the hinges is *EF = 1.0068* or *906 mm;. FB = 0.0872* or *78.5 mm;* angle *β= 0.12°;* angle *α=46.64°; Δα = ±2.3.* Graphically changeability of the angle is showed in figure 2.

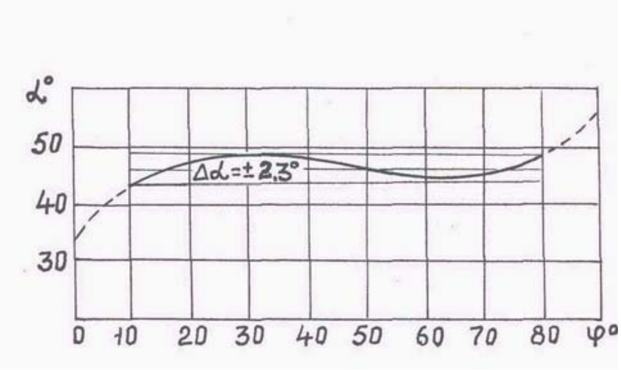

Figure 2. Graphically changeability of the angle

The received values of-the synthesis parameters were used in the construction of the lab sample of grab. The result of the lab research showed us, that developed mechanism provided the straight linear progressive movement of jaws in the construction of the grab. Measuring the efforts on plunger and lower cutting edge of jaws was revealed that when the jaws are closed - the power mechanical advantage equals four. When the diameter of hydro-cylinders is 60 mm and when the pressure of hydro-system is 16 MPa, the effort of abridgement is 11 kH. When the jaws are open, the grab seizure is 2.6 m, and when they are open -3.5 m. The height of the clamshell to the upper eyelet is 2.3 m.

3. CONCLUSION

The constructed control algorithms allow to detour the obstacles, move in straight and curve trajectories with the specified speed, to decrease the rate of construction's movement, to perform orientation of construction and provide its smooth installation into the projective position.

4. REFERENCES

1. Tauber B.A. Grab mechanisms. Theory, calculations and constmction.- M.: Machine Building. 1967. - 424 p.
2. Bogdanov V.V., Bogdanov V.I. Crank pulling mechanism with a section moving in a straight-parallel way . Author's certificate USSR № 1605059. // Bulletin of inventions, 1990.- № 41. - p. 169.
3. Shup. T. Solving of engineering problems on P. C. Maintenance instruction. - M.: Mir. 1982.-235 p.
4. Bogdanov V.V. and others. Grab. Author's certificate USSA. № 1631132. // Bulletin of inventions. - 1991. - № 8. - p. 80.
5. Bogdanov V.I. Grab for channel cleaning Author s certificate USSA № 1023034 // Bulletin of inventions. 1983. - № 2. - p. 145.