

# THE PRACTICAL USAGE OF THE PATH GENERATING LINKAGE MECHANISMS AND DWELL MECHANISMS ON THEIR BASIS

Kharzhevskiy V.<sup>1</sup>, Nosko P.<sup>2</sup>, Marchenko M.<sup>1</sup>

<sup>1</sup> Khmelnytskyi National University, Ukraine

<sup>2</sup> National Aviation University, Ukraine

## 1. Introduction

The intermittent motion of the output link of the mechanisms during continuous rotation of the input link is necessary in many cases and is required in different types of modern machines. During the periodic dwell of the output link a technological operation can be performed, for that purpose the various types of mechanisms can be used, for example: cam mechanisms, nonfull teeth gear mechanisms, Geneva-type mechanisms etc. As known, that problem can be also solved with the linkage mechanisms which have only lower kinematic pairs and geometric closure of the links, unlike the other types of mechanisms. It enables to significantly increase the working velocities of machines, their durability and reliability and increase the load-carrying capacity. But the main problem of the practical usage of linkage mechanisms is their complicated kinematic synthesis.

For designing the mechanisms with a periodic dwell of the output link, path generating linkages can be used. In particular, basic circular and straight-line path generating mechanisms. Nowadays, many methods of such mechanisms' synthesis are developed, which have two main directions: the first one is the usage of algebraic Chebyshev's methods and the second one is the usage of the kinematic geometry methods which are grounded by Burmester L. Further development of the Chebyshev's methods was carried out, in particular, by Blokh, Kinytskyi [4], Sarkissyan [11], Gassmann [1]. The kinematic geometry methods were further developed by Müller [8], Beyer, Lichtenheldt, Cherkudinov, Murray [6], Yin, Han [13]. The modern state of the theory of synthesis of linkages is presented in the works of McCarthy [7], Wang [14].

The main principle of the synthesis by kinematic geometry methods, according to the curvature theory, is to find such special points in the coupler plane of the mechanism, that can be taken as trace points, which are the multiple knots of interpolation, and which satisfy the criteria of the high order tangency of coupler curve to its tangent circle in this point. In particular, one of special

points of the coupler plane that can be used to synthesize straight-line and circular path generating linkages with good approximation to an arc or to the straight line are: Ball's point, Burmester point, Chebyshev's point (Ball-Burmester) which are defined for several infinitesimally close positions of the coupler of the mechanism.

Linkage mechanisms are widely used in various fields of modern engineering, in particular in light industry, food, agricultural, printing, hoisting and many other machines. As revealed by the analysis of literary sources, planar linkage mechanisms are characterized by a variety of structural schemes and usually have from 4 to 14 links. The simplest one is a four-bar linkage mechanism, which can be used as a straight-line and circular path generating mechanism, as well as a basic mechanism for designing mechanisms with a dwell of the output link, as we are going to show below.

Thus, the main goal of the article is to show the samples of path generating linkages and dwell linkages in several practical cases.

## 2. Samples of straight-line linkage mechanisms and their application.

In Fig. 1, *a* the mechanism that is intended for the attachment of the coulters of the seed drill is shown. This mechanism is specific, it has no input link, and is driven by a connecting coupler, which is the axis of attachment of the disk coulters.

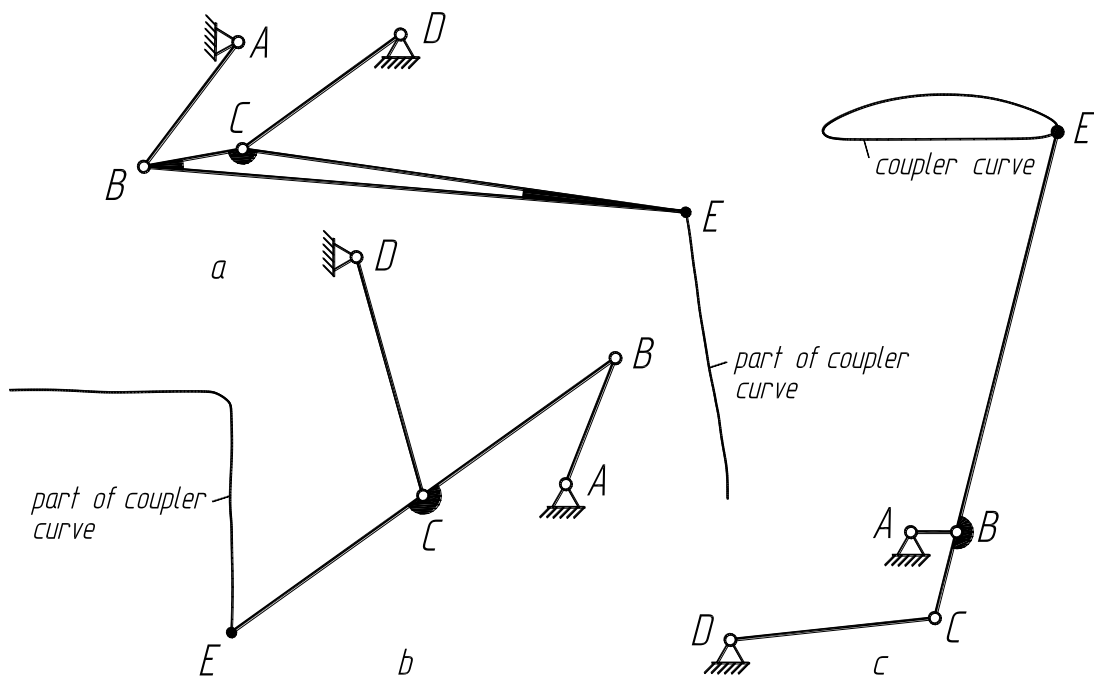


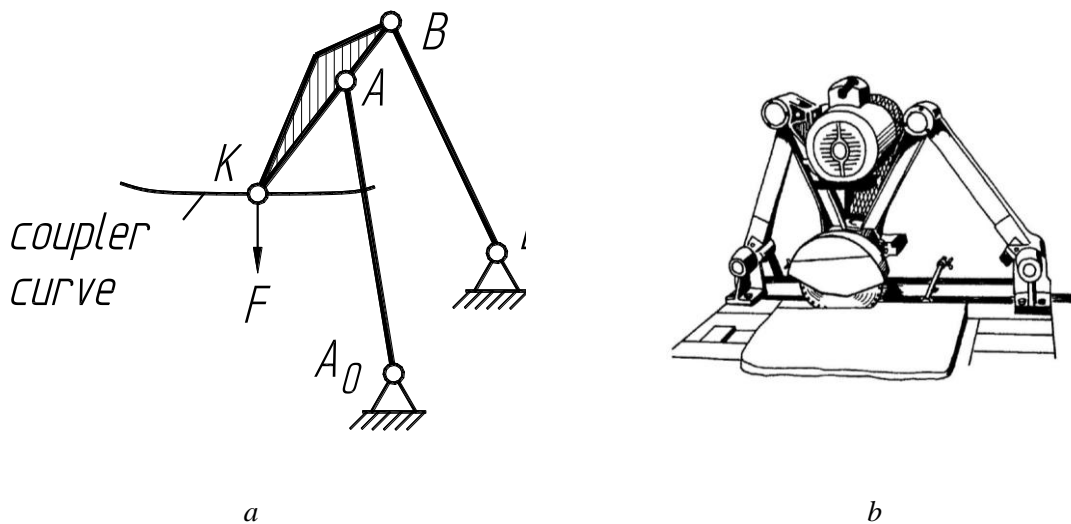
Fig. 1. Straight-line four-bar linkage mechanisms [3]:

a) mechanism of attachment of the seed drill couplers; b) drive mechanism for the traverse of tire vulcanizer; c) picking mechanism of the loom

The mechanism reproduces the predetermined linear motion of the coulters and was synthesized by Kikin A.B. [3]. In Fig.1, *b* a path generating mechanism that is designed to drive the top traverse of a tire vulcanizing machine is shown. The trajectory of the working point of the mechanism has two straight-line sections, located at an angle of 90 degrees. [3].

In the picking mechanism of the loom [3], shown in Fig. 1, *c*, the working point trajectory has a 300 mm straight-line section that corresponds to the crank angle  $\alpha_{\Sigma} = 90^{\circ}$ . The contact between the picker and the shuttle occurs only on the specified straight-line section, with a maximum deviation from the straight line of 0.25 mm. Mechanisms of this type are also used by «Saurer» company.

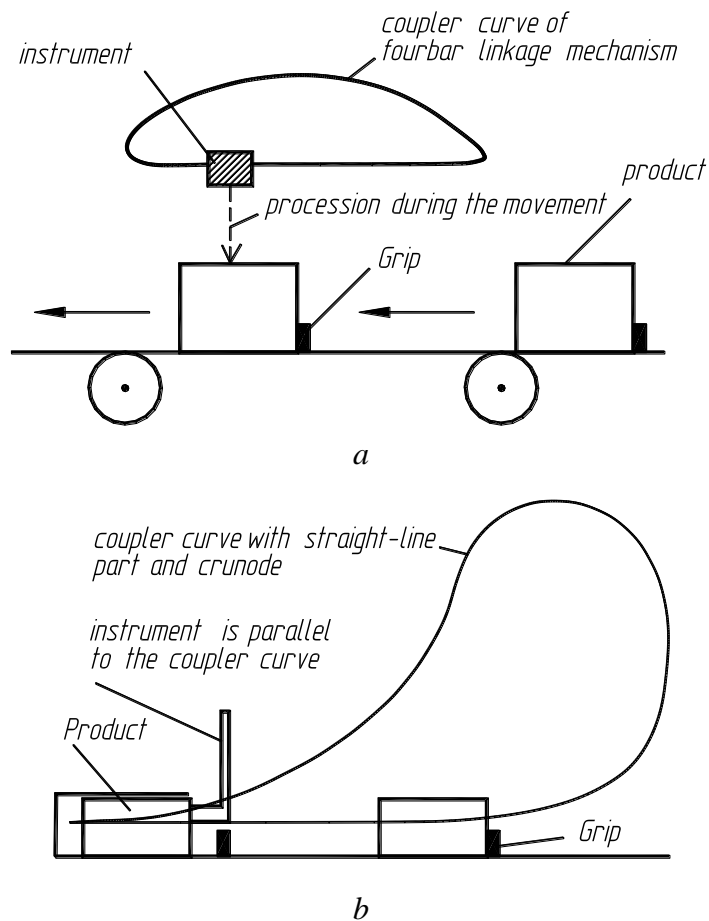
In Fig. 2, *a*, a lifting arm of the crane mechanism that acts as a two-balance four-bar mechanism is shown. As required, a lifting arm must retract and return with the lowest energy cost, and its point *F* should trace a trajectory approaching a straight line. The mechanism of power-saw benches [1] that is based on the four-bar straight-line linkage mechanism is shown in Fig. 2, *b*. The circular saw receives rotary motion from the motor located on the connecting coupler. During the cutting process the saw is moved along the straight line. Not all the connecting coupler curve is used, but only its straight section.



**Fig. 2. Examples of application of straight-line four-bar mechanisms:**  
a) portal crane mechanism; b) mechanism of power-saw bench

One of the modern fundamental works that is dedicated to the synthesis of the Chebyshev's straight-line linkage mechanisms, by means of numerical

methods, is the dissertation paper of Gassmann F. [1]. There are several practical examples of such mechanisms in this paper, some of which are shown in Figs. 3. In particular, in Fig. 3, *a* a diagram of parts' processing on a belt conveyor is shown. To save time, products must be processed while moving at constant speed. For example, a label may be stuck on, drilling operation can be performed, or a bottle can be filled. In the first two cases, it is necessary to provide a straight-line directional movement for the tool, and in the third case it is sufficient to point the filling head-dispenser on the top of the bottle. The movement is carried out in accordance with a predetermined stroke, to prevent collision with the next product a linkage four-bar mechanism with a D-shaped coupler curve is required.



**Fig. 3. Examples of the use of straight-line four-bar linkage mechanisms [1]**

In the work [1] is also shown the case of the practical usage of the Chebyshev's mechanism, its connecting coupler's curve is completely approaching to the straight line. This mechanism is used to receive products from the conveyor belt, then a predetermined movement to the next stage of processing can be performed [1]. In Fig. 3, *b* a diagram of inserting a tool into a

narrow pipe is shown. The task is to insert the tool into a narrow pipe or the workpiece into a magazine (for example, in the form of a rotary revolver head). In the paper [1] it was shown that by using a path generating linkage mechanism with a straight section of a coupler curve and a cusp point, it is possible to refuse the usage a folding mechanism and thereby simplify the construction.

In the paper of Polyakov B.N. [10] it was shown the solution of the problem of synthesis of a four-bar linkage mechanism of ingots (blanks) pusher in order to reproduce a given straight-line trajectory of its executive link – a coupler. The task was to synthesize a mechanism with the length of a straight section (the distance between the axes of the fixed joints was taken as a unit). In addition to the above examples, the four-bar linkage mechanism is used as a basic straight-line mechanism in many other machines, among which there is a mechanism for compensating position errors during automatic assembly [1], a straight-line mechanism for the needles of high-performance sewing machines [1]. In the work of Semin A.G. [12] a four-bar linkage straight-line mechanism is used to design the six-linked needle mechanism of a overlock sewing machine of 508 class, its coupler is opened, that causes the needle to move exclusively in a straight line.

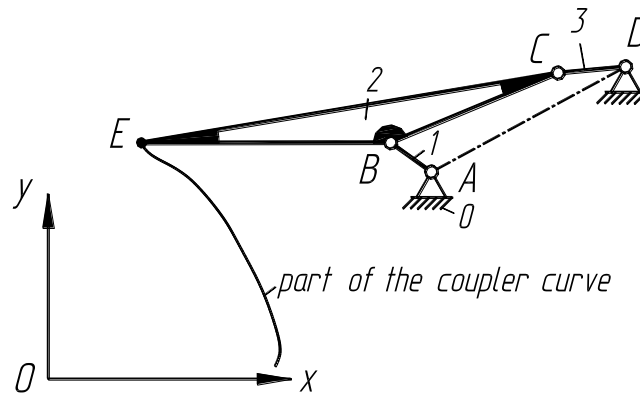
### **3. Samples of circular path generating linkage mechanisms.**

Several examples of straight-line path generating mechanisms have been considered above, but circular path generating mechanisms are also used in mechanical engineering to approximate some part of the coupler curve to the arc of the circle, as well as six-linked mechanisms with the dwell of the output link on their basis. Such mechanisms will be considered below.

#### ***Mechanism for the traverse drive of the Schlafhorst winding machine.***

In the Fig. 4 a kinematic diagram of a circular path generating mechanism for the drive of the traverse mechanism of a winding machine is shown, the synthesis of which was considered by Kikin A.B. [3]. The task was to upgrade the existing winding machine produced by the German company Schlafhorst, which uses a circular path generating four-bar mechanism, the part of the coupler curve approximates to the arc with a radius of  $R = 236.1$  mm, the swing angle is  $64^\circ$ . As was established, the existent mechanism was characterized with non-optimal transmission angles with the minimal value of  $\mu = 16^\circ$ , maximum deviation from the specified trajectory was 8.4 mm. As a result of optimization

synthesis, using the numerical methods given in [3], the author was able to increase the minimum transmission angle to the  $\mu = 19^\circ$ , deviation was reduced to the value of 3.1 mm.



**Fig. 4. Mechanism for the traverse drive of the Schlafhorst winding machine**

It should be noted that in order to provide better transmission angles, a six-linked path generating mechanisms (instead of four-bar) were synthesized and as it is shown in [3], in that case the theoretical deviations can be reduced and the minimum transmission angle may be increased, but the main disadvantages of such mechanisms is a complexity of the structure: in this case the mechanism already has seven hinges.

***The linkage mechanisms of the “Kokett” warp-knitting machine.*** Modern warp-knitting machines often use linkage mechanisms instead of cam mechanisms in order to increase their speed and productivity. As noted in [2], the most difficult task is the design of linkage mechanisms which provide dwells of the looping mechanisms at the certain angles of rotation of the main shaft of the machine. At the same time, it is noted in [2] that six-link mechanisms are usually used to provide the dwell of the output link with the duration of  $\alpha_\Sigma < 90^\circ$ , and for longer dwells the number of links must be increased. In the “Kokett” warp-knitting machine, the looping process is carried out by means of compound needles using linkage mechanisms (Fig. 5).

In particular, in Fig. 5, *a*, the scheme of the mechanism of the needles, driven by a crankshaft  $O_1A$ , which is a crank. An *MO* linkage is pivotally connected to the connecting rod *AB* of the mechanism at point *M*, which drives the needle *H* with needles. The position of the point *M* on the coupler is chosen in a way that its trajectory has a part with approximately constant radius of curvature *R*. If the length of the link *MO* is taken equal to the radius *R*, then the

needle will have practically no vertical movement in the upper position, as the hinge  $M$  moves along its trajectory  $\alpha-\alpha$ . Using the same principle, other mechanisms of the “Kokett” machine work, in particular – mechanism that drives the eyelet (Fig. 5,  $b$ ) and the compound needles (Fig. 5,  $c$ ).

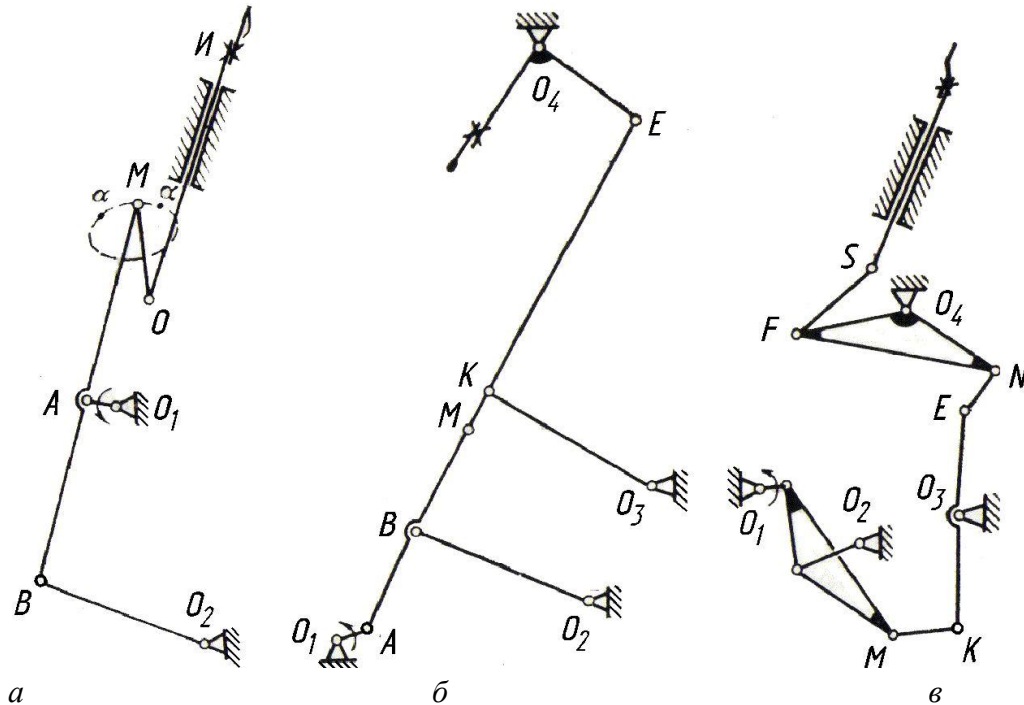


Fig. 5. Linkage mechanisms for “Kokett” warp-knitting machine [2]

**Tilter for multilayer baking hearth furnace.** In Fig. 6 a tilter for the multilayer baking hearth furnace [5] is shown, which automatically removes bakery goods 2 from the steel belt 1 (mesh) of the conveyor of the top layer furnace and places them on the belt 6 (grid) of the lower layer of the conveyor.

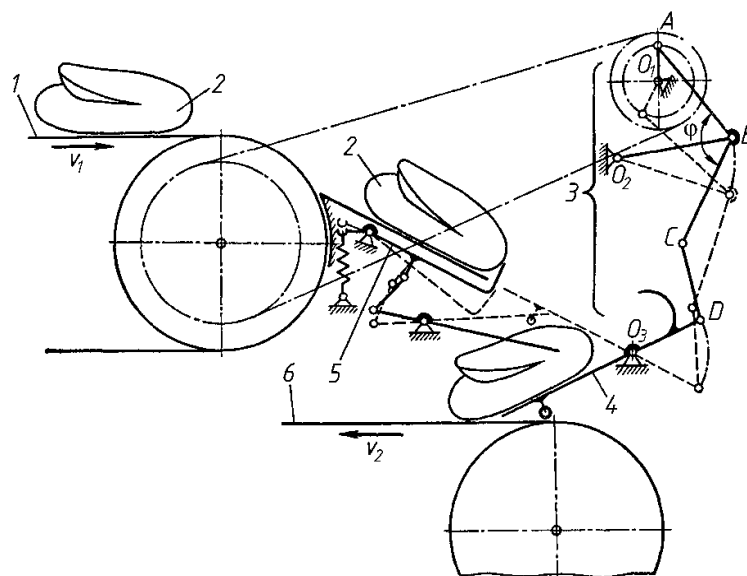
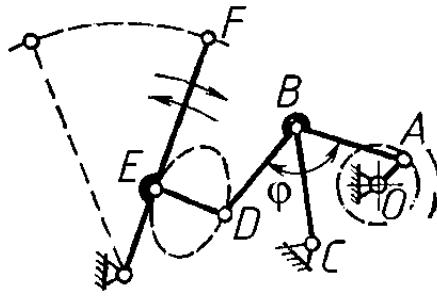


Fig. 6. Tilter for multilayer baking hearth furnace



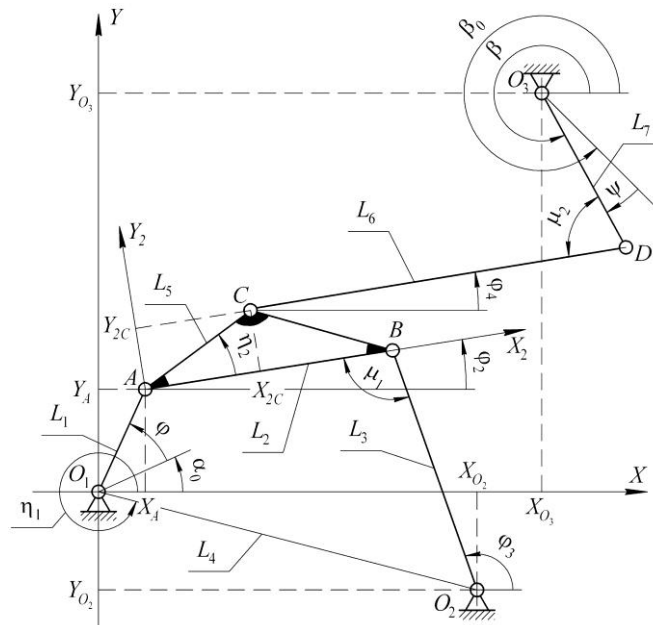
**Fig. 7. Kinematic diagram of the tipping mechanism**

The tilter consists of a chopper 5, a gripper 4, which performs oscillatory movement and a six-linked mechanism 3, which provides oscillations of the gripper 4 with its long dwell in the lower position and synchronous operation of the mechanism of the chopper. Chopper 5 and gripper 4 are located inside the furnace, and the coupled mechanisms that drive them are located on the outside of the furnace [5].

The scheme of the mechanism is shown in Fig. 7, which principle of work is similar to the mechanism that is shown in Fig. 5, a.

The mentioned mechanism is a mechanism of II class, which is based on a circular path generating four-bar linkage mechanism, with the joined structural group of the 2<sup>nd</sup> order of 1<sup>st</sup> type (according to the Assur-Artobolevsky classification). The length of the connected coupler of the joined structural group is chosen equal to the radius of the approximated part of the coupler curve. When the coupler point passes through this part of the coupler curve, the output link of the mechanism will have an approximate dwell.

***The mechanism of transportation of materials in the sewing machine of 131 class*** (Fig. 8). In modern sewing machines, a number of different linkage mechanisms are used to drive the working mechanisms. The most complicated and loaded mechanism of the sewing machine is the mechanism of transportation of materials. The operation of this mechanism significantly affects the quality of the stitching, the productivity of the sewing machine, its vibration and noise. As noted in the dissertation paper of Polotebnov V.O. [9], one of the directions of improving the mechanisms of material transportation is to obtain a straight section of the trajectory of the gear rack, parallel to the needle plate. It also should be taken into account the conditions of timely interaction of the working mechanisms of the sewing machine in different modes of its operation.



**Fig. 8. Six-linked kinematic chain with a dwell of the output link in the mechanism of transportation of materials of the sewing machine of the 131 class [9]**

In the paper [9], a method of synthesis of a kinematic chain of vertical displacements of a rack and a kinematic scheme of the mechanism of material transportation were developed. To implement the necessary function of moving the output link, a six-linked linkage mechanism with a dyad attached to the connecting rod of a basic linkage four-bar mechanism was used, its kinematic scheme is shown in Fig. 8. According to the cyclogram of the machine, this mechanism should provide periodic dwell of the output link  $O_3D$ , and in the paper [9] this problem was solved by the optimization methods and thus the author obtained 3 kinematic diagrams of the mechanism with the dwell of the output link respectively  $\alpha_{\Sigma} = 40^{\circ}, 60^{\circ}, 80^{\circ}$ .

**4. Conclusion.** Linkage path generating mechanisms are widely used to drive the various technological machines. As mentioned above, there are mechanisms, working points of which in some part of the trajectory should move along a straight line or along the arc of a circle. Such mechanisms can also provide a dwell of the output link. In particular, such movement of working bodies is necessary in the warp-knitting, combing, winding and other light industry machines, other various fields of modern engineering. But the main problem of the practical usage of such mechanisms is their complicated kinematic synthesis, which can be successfully solved by using numerical and analytical kinematic geometry methods.

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