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METHOD FOR CONSTRUCTING ROCKER MECHANISMS WITH FLEXIBLE LINKS ACCORDING TO ASSUR

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Abstract:
The article deals with the issues of kinematic analysis and synthesis of rocker mechanisms with flexible links. A new method for the synthesis of such mechanisms using graph theory is proposed. Also shown are all kinds of kinematic diagrams of rocker mechanisms with flexible links.

Keywords: Mechanism, kinematic pairs, isomorphism, kinematic chain, Assur principle.

It is known that in the theory of mechanisms there are a number of principles for the structural classification of flat lever mechanisms, of which the principles of Assur and Grubler can be considered the main ones.

Assur's principle is as follows: groups of links with a zero degree of relative mobility are attached to the input link and the rack. For the mechanisms studied by us, Assur groups contain kinematic pairs of the fifth class, and therefore the number of links and the number of kinematic pairs of such groups are related by the ratio: 3 = 2p.

Grubler's principle is based on the concept of a closed kinematic chain. The classification of mechanisms formed according to the Grubler principle begins with the classification of kinematic chains. The classification of kinematic chains should include assignment to various classes of kinematic chains, the degree of mobility of which corresponds to the number of degrees of freedom of mechanisms and chains formed from them that do not satisfy this property.

Solving the problem of enumerating various structural diagrams of kinematic chains as the first stage in the implementation of the Grubler principle, some authors propose to synthesize complex kinematic chains by successively connecting links or groups of links to simpler ones. If in this case the group of links to be attached has a degree of mobility other than zero, then the degree of mobility of the resulting kinematic chain will differ from the degree of mobility of the original one.

Therefore, when crossing the kinematic chains of a given degree of mobility, the Assur groups have to be added. Alternatively, adding some links, throw out others so that the degree of mobility does not change.

If we restrict ourselves to enumerating only the mechanisms of a given class K, then, following Assur's principle, it is necessary to add groups of a class not higher than K, i.e. groups belonging to a known list. The implementation of the Grubler's principle in this setting loses its meaning or is reduced to the Assur principle. The main contribution to the theory of the structure of flat lever mechanisms was made by scientists: L.V. Assur, I.I. Artobolevsky, G. Baranov, O. G. Ozol, S.N. Kozhevnikov and others. Artobolevsky's classification is based on the Assur principle. Baranov's classification, having a number of features, is also based on the Assur principle. The principle of constructing Assur mechanisms creates favorable conditions for the development of rational algorithms for the kinematic and kinetostatic analysis of mechanisms based on the application of the modular method of analysis, in which the mechanism is naturally divided into separate modules - structural groups.

Here undirected graphs without loops and multiple edges are considered. In the figures, the vertices of the graphs are depicted by dots: a line connecting the corresponding points depicts an edge identical to two adjacent vertices. As a rule, all considered graphs are marked, i.e. their vertices are numbered with sequential natural numbers (starting from 1), this, of course, does not apply to subgraphs: for an arbitrary subgraph H of graph G, the set V (H) of vertices of graph H is a subset of the set V (G) of vertices of graph G: $V(H) \supset V(G)$; the set X (H) of the edges of the graph H is a subset of the set X (C) of the edges of the graph C: $X(H) \supset X(C)$.

A subgraph H of a graph C is called a skeleton if the sets of vertices of the graphs H and C are equal: V (H) = V (C). If, moreover, the graph H is a tree (that is, it is connected and has no cycles), then H is called the skeleton of the graph C.

Any labeled graph C is uniquely defined by its adjacency matrix A (C): the element aij in the i-th row of the j-th column of the matrix A (C) is equal to 1 if the vertices i, j are adjacent (by a connecting edge), and aij = 0 otherwise.

The isomorphism of the graphs C and C 'is determined by the one-to-one correspondence of the sets V (C) and V (C'), in which two vertices of the graph G are adjacent only if the corresponding vertices of the graphs C 'are adjacent.

Let V (C) = {1,2, …… .., n} = V (C '); an isomorphism of graphs $C \cong C'$is determined by a one-to-one mapping G: V (C) → V (C′), that is, permutation of a set of n elements. Denoting by A(C′)= (a_{ij}) the adjacency matrix of the graph C', we obtain: a_{ij}=1, if and only if a $a_{\sigma(i)\sigma(j)}$=1, i.e. $a_{\sigma(i)\sigma(j)}$=1{1,2, ……, n}.

The permutation σ defines a matrix ∑ of zeros and ones, in which the element of the i-th row of the j-th column ($1 \leq$ i; j $\leq$ n) is equal to 1 if and only if σ (i) = j; in this case, obviously, $\sum^{-1} = \sum^{t}$ – the transposed matrix corresponds to an inverse permutation. The multiplication of the matrix on the right by the adjacency matrix A (G) acts as a permutation σ of the set of columns of the matrix A (G), and the multiplication of the matrix ∑ on the left by A (G) acts as the same permutation of its rows.By a root graph we mean a (labeled) graph with distinguished (ordered) subsets of the sets of vertices and edges; these distinguished sets are called the root. A subgraph of a root graph is called root if it contains a root; the root skeleton is determined accordingly. A root isomorphism is a root graph isomorphism such that the image of the root of one graph is the root of another. A kinematic chain graph is a graph whose vertices are in one-to-one correspondence with the links of the kinematic chain, and two vertices of the graph are adjacent if and only if the corresponding links of the kinematic chain form a kinematic pair. For example, the kinematic chain in Fig. 1, a corresponds to the graph in Fig. 1, b.

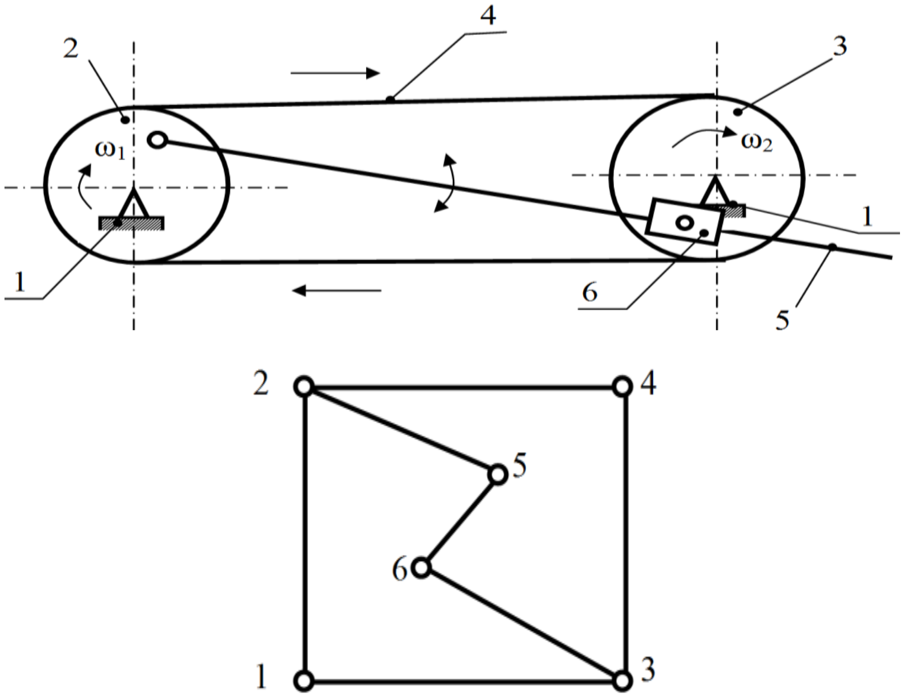
Having fixed one link in a given kinematic chain (taking a stand for it) and setting the relative motion of some others (indicating one or several - depending on the degree of mobility - input links), we can obtain mechanisms of various classes. For example, taking in the kinematic chain (see Fig. 1, a) for the rack link **a** and indicating the input link **b**, we get a mechanism of the second class, and specifying the input link **l** and indicating the input link a, we again get the mechanism of the third class, but specifying the input link link **f** - we get a mechanism of the fourth class. Thus, comparing the graph of its kinematic chain to a given mechanism, it is natural to select in the latter the vertex corresponding to the rack and the vertices corresponding to the input links. In other words, it is natural to associate the root graph with the mechanism.

The mechanism graph is a labeled graph, the vertices of the graph are numbered as follows: 1 - rack, 2 - input link, 3, 4, etc. - other moving links.

As a simple example shows, a flat engine graph can be flat. The graphs of flat one-moving mechanisms, constructed according to the Assur principle, are obtained as follows. Consider two adjacent root graphs of a vertex corresponding to a post and an input link. The joining of the simplest two-lead Assur group to the strut and the input link corresponds to the joining to the selected vertices and four edges - a simple cycle of length 4, which is a four-link graph.

The joining of the second, the same Assur group, corresponds to the joining of another chain of three edges to two different vertices of the four-link graph.

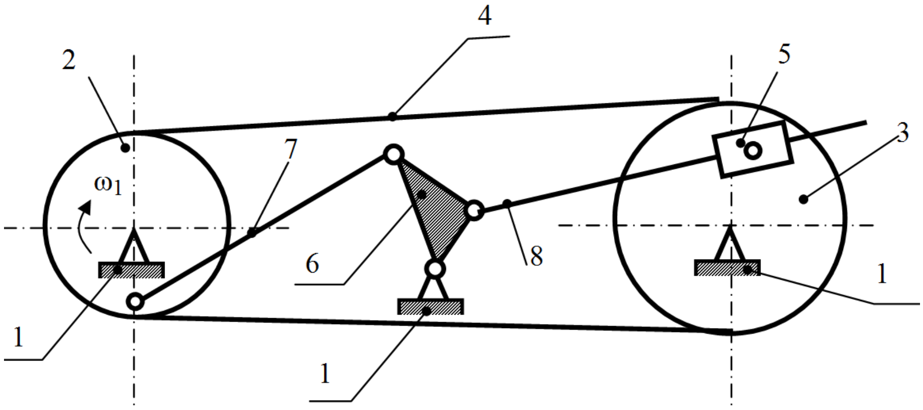
The root of the graphs of such mechanisms will be the graph of the original first-class mechanism, i.e. two vertices and an edge incident to them. We give a formal definition of the class of graphs under consideration by induction.



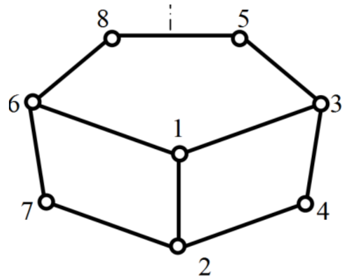
a

б

Fig. 1. Six-link rocker mechanism with flexible link and its graph

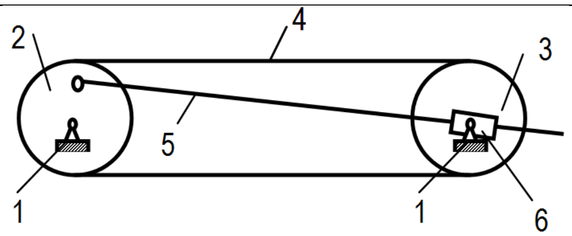
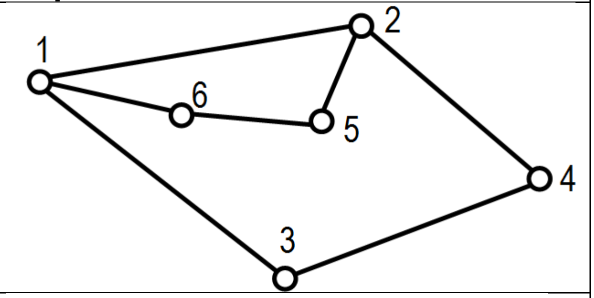
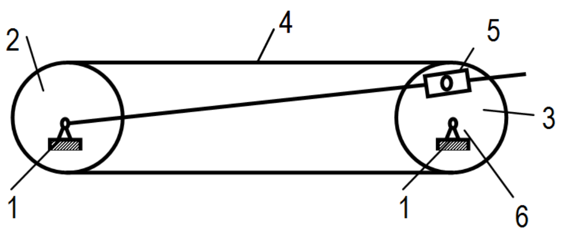
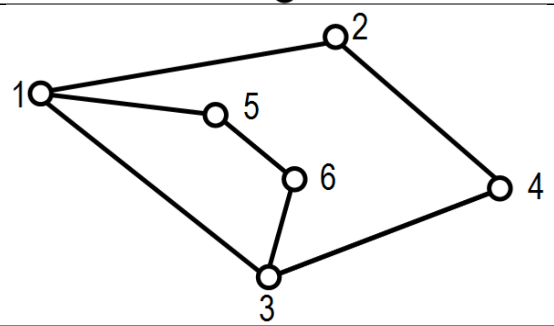
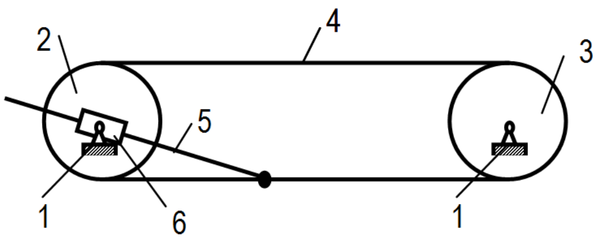
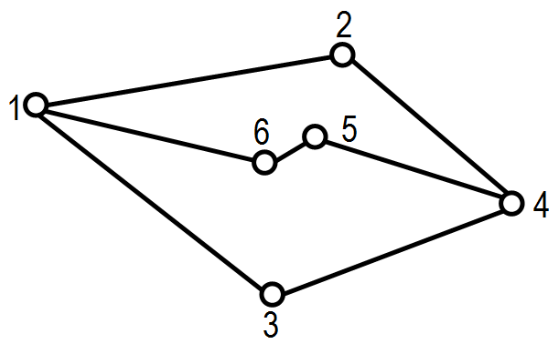


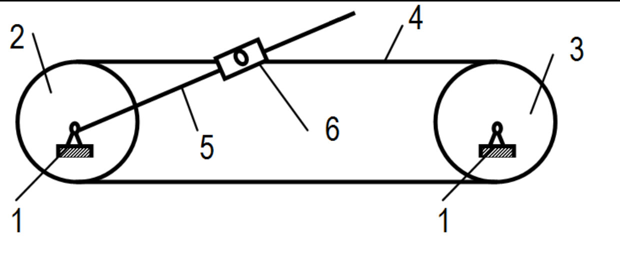
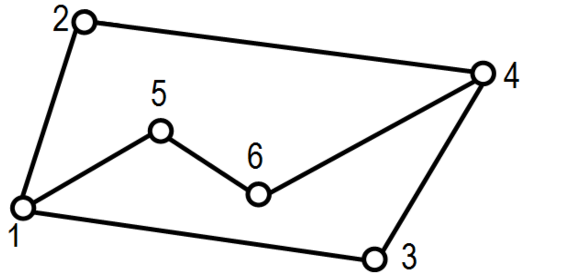
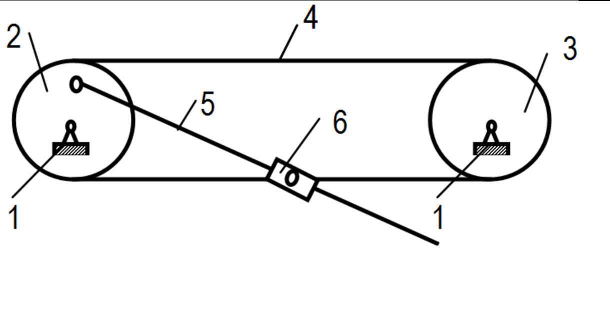
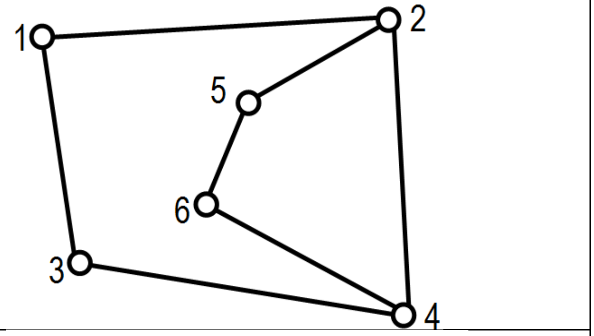
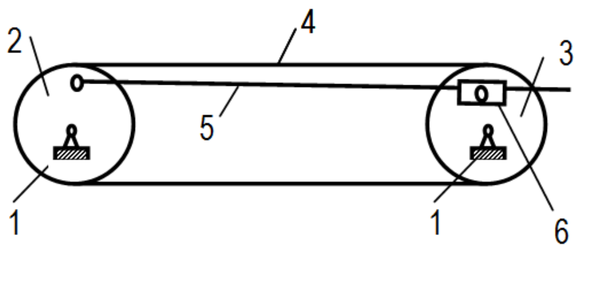
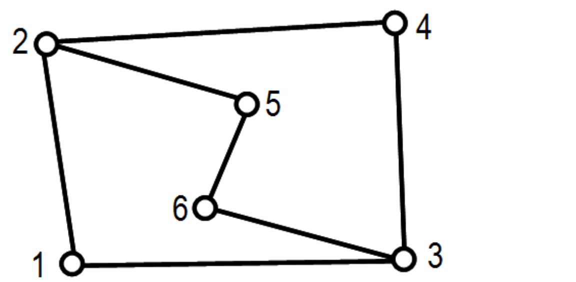
a



б

Fig. 2. Kinematic diagram of rocker mechanisms with flexible links with a three-drive group and its graph

№	Mechanism	Graph
1		
2		
3		

4		
5		
6		

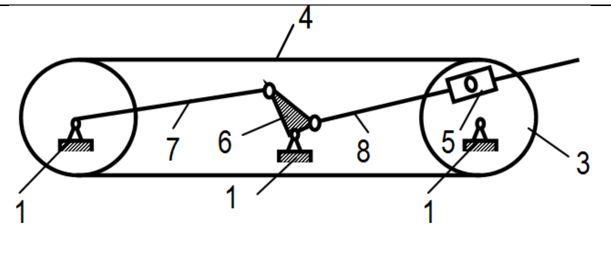
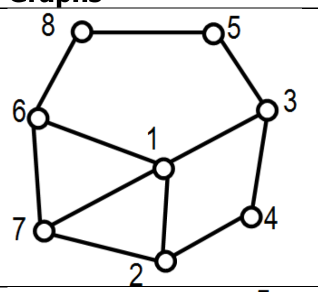
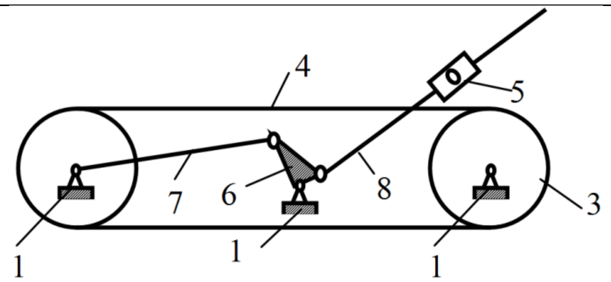
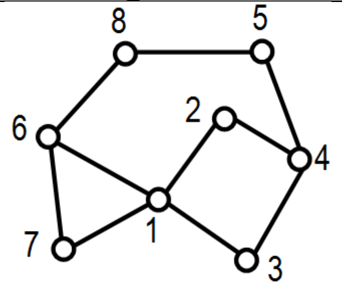
Structural synthesis of the lever mechanism is one of the directions of the design stage of the mechanism.

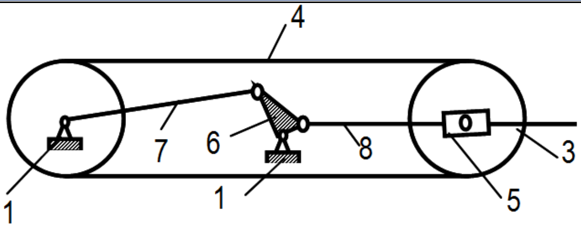
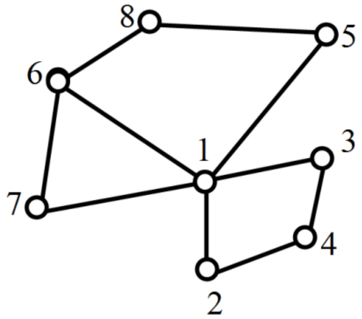
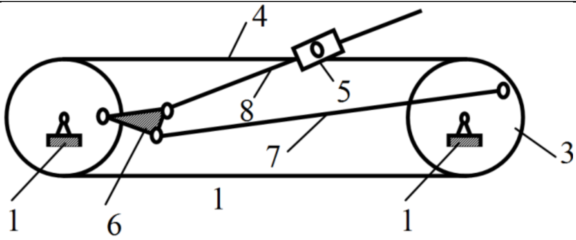
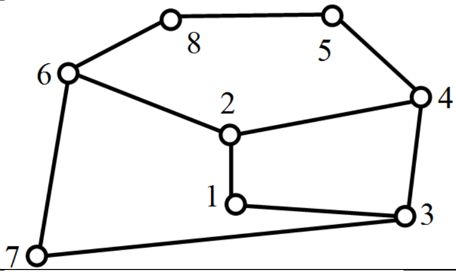
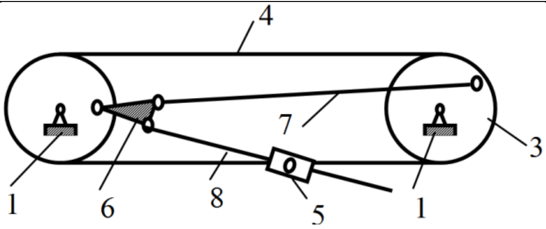
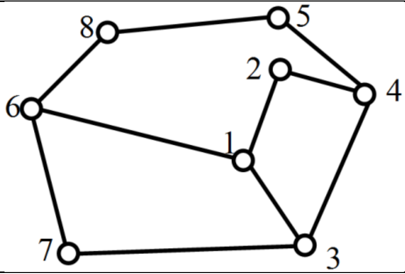
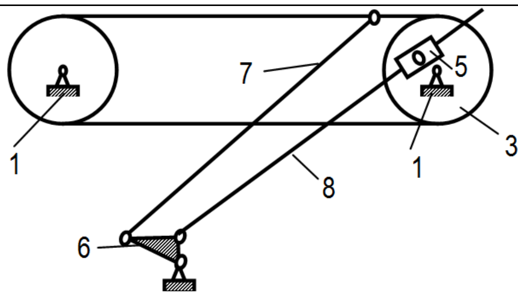
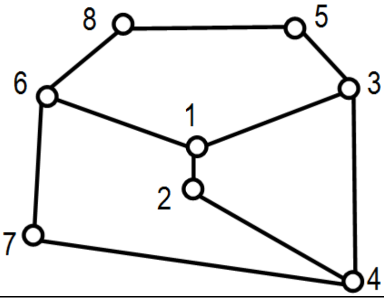
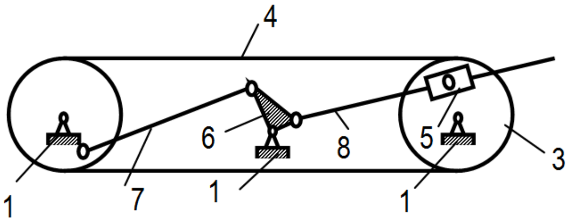
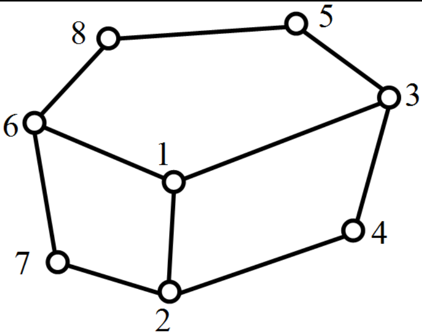
The paper considers structural diagrams of various types for n-link hinge mechanisms of the second class.

The synthesis of flexible link linkage mechanisms based on the use of graph theory results in all the different repetitive structural schemes.

Using graph theory, the problem of enumerating all kinds of mechanisms for a six-link rocker mechanism with a flexible link is formulated as follows: the tops of the graph are designated: rack 1, crank pulley leading 2, driven pulley 3, flexible element 4, rod 5, stone 6 (Fig. 1.) ... Further, a satisfactory formalization of the notion of difference between structural schemes is achieved using the notion of isomorphism of feather graphs. (see Table 1., Fig. 3, 4.).

Table 1
Structural diagrams of eight-link rocker mechanisms with flexible links with three drive group

№	Mechanism	Graphs
1		
2		

3	 4 7 6 8 3 1 1 5	 8 5 6 1 3 7 4 2
4	 4 5 8 7 3 1 6 1 1	 8 5 6 2 4 1 3 7
5	 4 7 3 1 6 8 5 1	 8 5 2 4 6 1 7 3
6	 7 5 1 3 1 8 6	 8 5 6 3 1 2 7 4
7	 4 6 8 5 3 1 7 1 1	 8 5 3 6 1 7 4 2

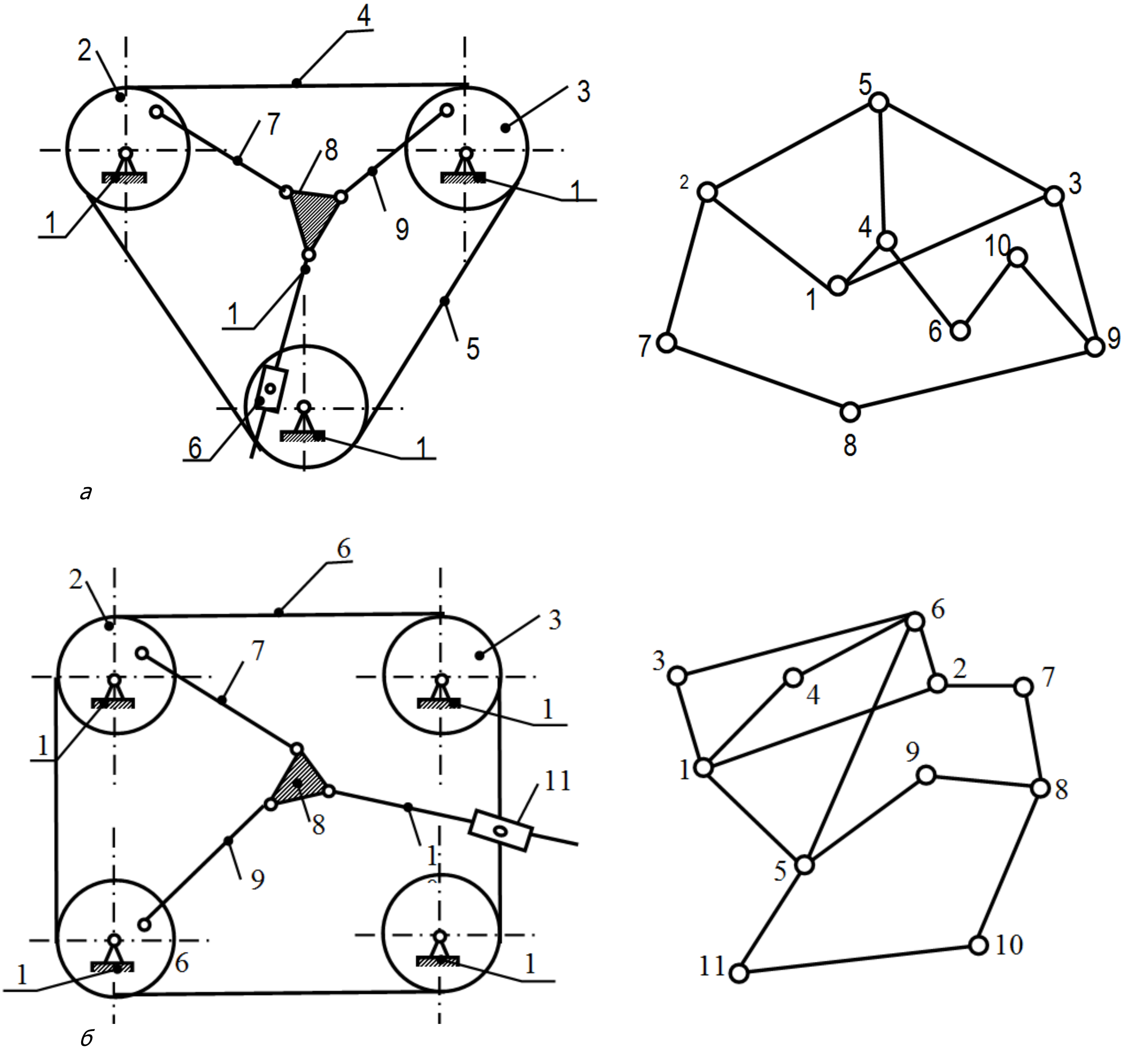


Fig. 3. Kinematic diagram of rocker mechanisms with flexible links and their graphs

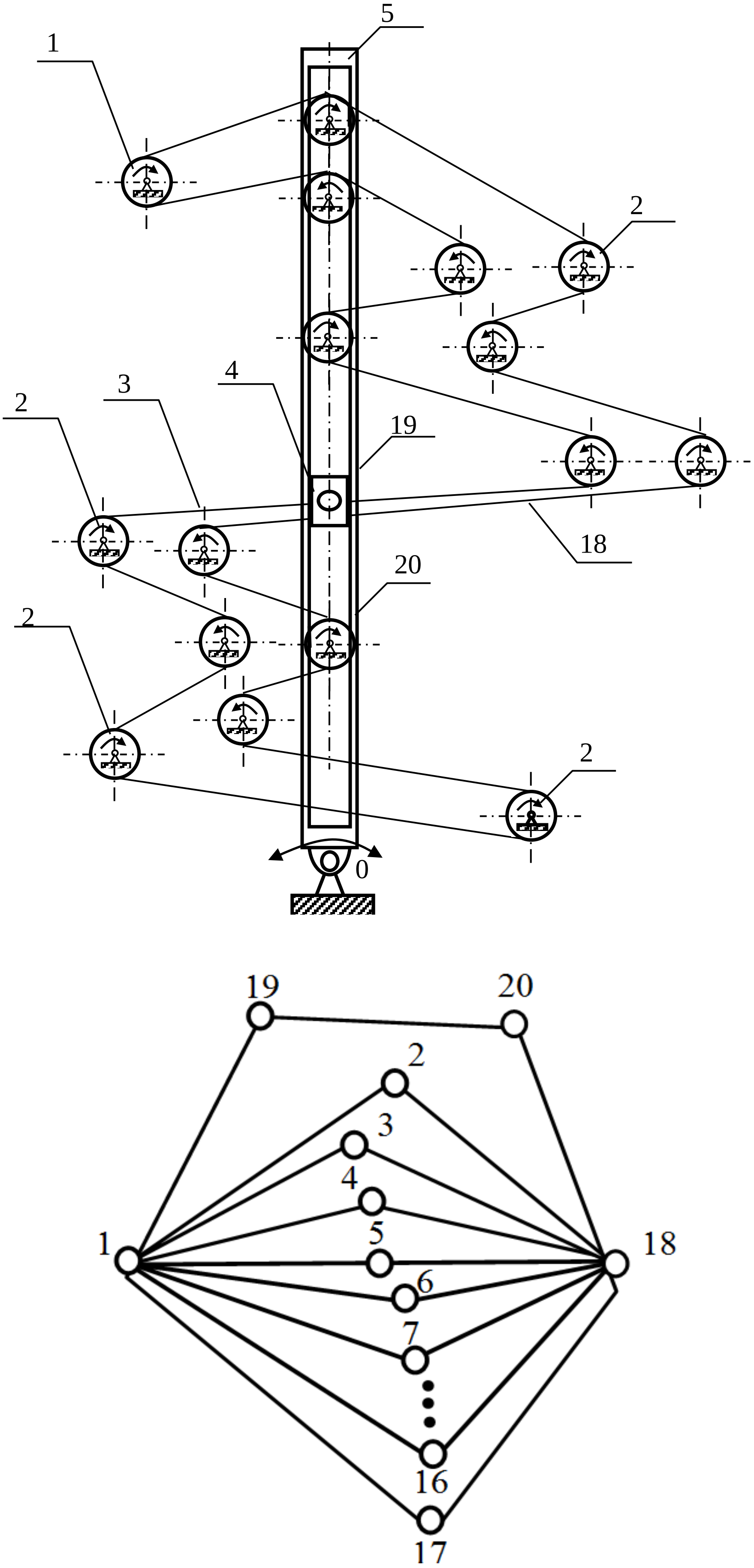


Fig. 3. Kinematic diagram of rocker mechanisms with flexible links and their graphs

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