Graphanalytical Methods of Calculating Mechanisms Using a Computer

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ABSTRACT:Kinematic analysis of mechanisms is one of the types of research of mechanisms performed without taking into account the force factors acting on their links as a function of time. The purpose of the kinematic analysis is to determine the magnitudes, directions of action and patterns of change in the kinematic parameters of the mechanism under study as a function of time. In kinematic analysis, analytical, graphical and graphic-analytical methods are used. Both methods give approximately the same accuracy result. However, the diagram method is mainly used to determine the law of motion and the kinematic parameters of characteristic points of the output links of the mechanism. The method of computer plans allows finding the kinematic parameters of any points belonging to the links of the mechanism.

KEY WORDS: kinematic analysis, graphic-analytical, automation system, graph-analytical method, compass-graph.

I.INTRODUCTION

Attempting to use electronic computers to automate the kinematic analysis of mechanisms began in the 70s of the 20th century. Despite this, a complete solution to this problem still has not been presented, even for lever-hinged mechanisms. The reason for this is that the kinematic analysis based on the process-oriented approach under the control of a computer program is analyzed as a mathematical definition, in which all relevant movements in the design of a crank mechanism are expressed in the form of equations, inequality, logical conditions and mechanisms. Unfortunately, this model has not been created yet. Depending on the complexity of the mechanisms used, human capabilities are limited in solving such problems. Therefore, the search for new effective methods with the help of computer technology is an urgent problem of the mathematical software of automation systems.

II. LITERATURE SURVEY

The developed mechanism is a four-link lever-slider flat mechanism, the scheme of which is shown in Figure 1 [3].

The lever is rigidly connected to the slide mechanism. In the proposed mechanism, an elastic element is used - in the kinematic pair between the connecting rod and the slider - in the form of a rubber bush [6, 8, 9,].

When determining the kinematic characteristics of the material transfer mechanism, we take into account changes (only maximum and minimum values) of the connecting rod and crank lengths.

We will study the kinematics of the mechanism according to the existing analytical method of vector contours [1, 2, 3, 4].

III. METHODOLOGY

Graph-analytical methods for studying mechanisms in the theory of mechanisms and machines have been known and widely used since ancient times. They make it possible to determine the positions of the links, the trajectories of movement of individual points, the speed and acceleration of points and links of the mechanism, the reaction in kinematic pairs and estimate the accuracy of the mechanisms. These methods are based on geometric constructions, replacing analytical calculations and numerical operations. Graph-analytical methods are notable for their visibility, ease of control, and speed in solving a number of practical problems [1].

The main disadvantages of graph-analytical methods are: less accurate than analytical methods and often more cumbersome constructions, especially when trying to improve the accuracy of calculations. Recently, the most developed analytical methods for the study of mechanisms. It is also connected with the rapid development of computing technology.

However, in our opinion, one should not neglect the graph-analytical methods, which, with the advent of new computer graphics programs, while maintaining their advantages, have completely lost their shortcomings. The accuracy of graphical constructions has become comparable with analytical, and the need for cumbersome similar constructions is eliminated when using parametric graphical models.

IV. RESULTS

Let us demonstrate the possibilities that a computer can provide using graph-analytical methods for calculating mechanisms. For example, consider the crank-slider mechanism. As a tool, we will use the drawing and graphic editor Compass-Graph developed by Ascon [2].

A few preliminary notes

1. In the "Compass-Graph" environment, it is possible to parameterize the elements of a graphical construction, i.e. job specific links between them. We will create parametric models with specified parameter relationships both within the model and between different graphical models. The connection of parameters can be simple geometric, and can be calculated by any given mathematical dependence. Parameters can be both constant and variable values.

2. Graphic constructions of models are always carried out on a 1: 1 scale, and in the drawing they are depicted in a scale convenient for viewing by creating additional types.

3. Since when creating parametric models, some of the information about the parameters is depicted in the drawing and in the future because of its large number it can simply interfere, most of the parameterization operations are conveniently performed in a separately created drawing layer, which is subsequently made invisible (extinguished).
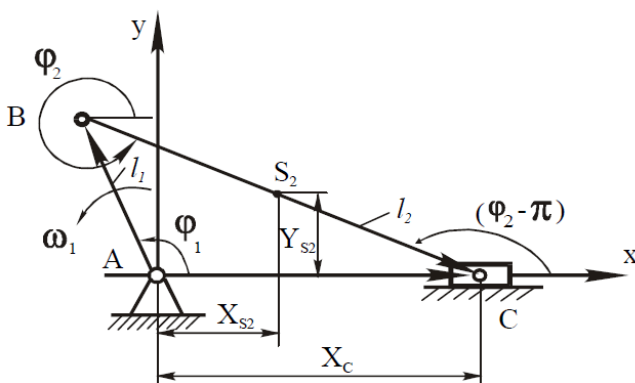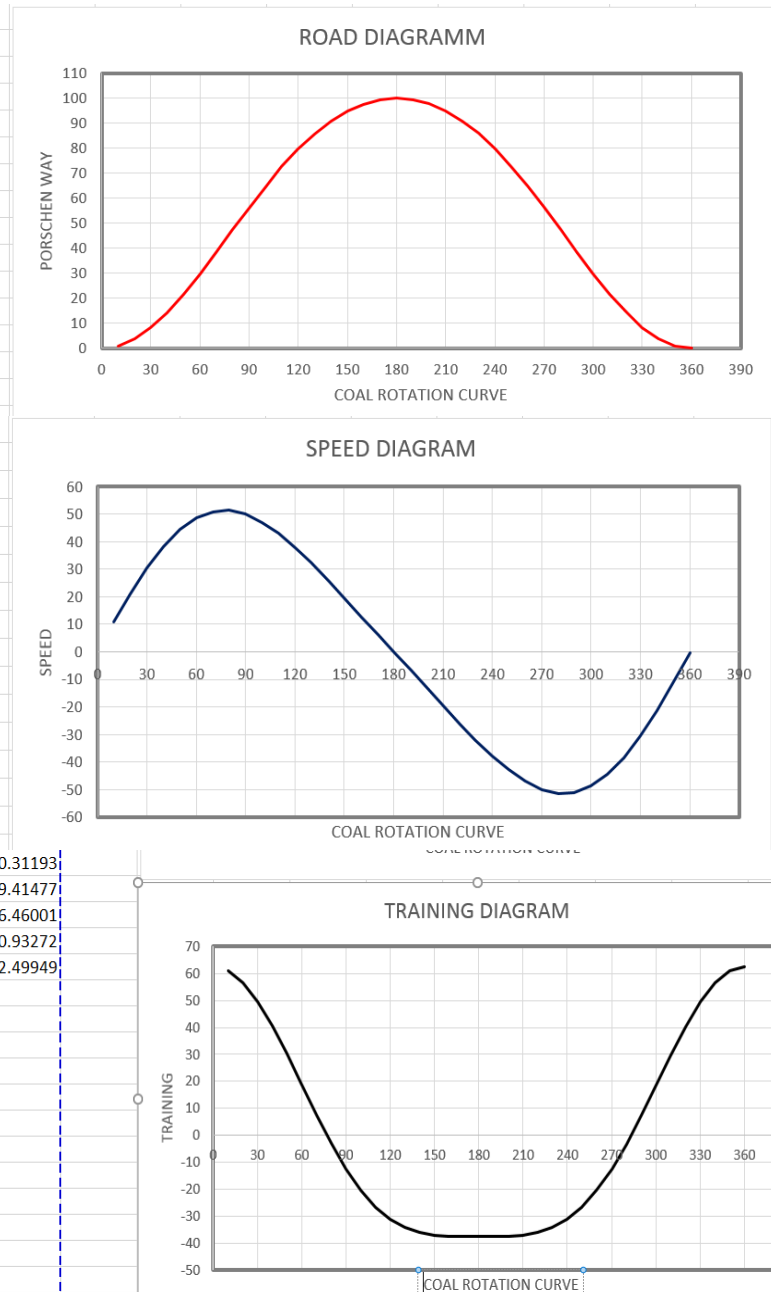

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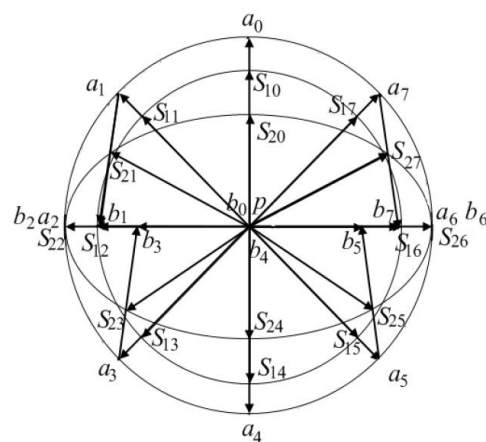
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#					
1	10.81463858	10	60.98807		
2	21.10842023	20	56.56606		
3	30.39950413	30	49.56365		
4	38.28010112	40	40.49291		
5	44.44400615	50	29.99661		
6	48.70396572	60	18.78448		
7	50.9973805	70	7.564509		
8	51.38016773	80	-3.022832		
9	50.00993823	90	-12.46017		
10	47.12082117	100	-20.39254		
11	42.99315781	110	-26.64645		
12	37.92177948	120	-31.22698		
13	32.18662969	130	-34.29422		
14	26.02908359	140	-36.12228		
15	19.63651313	150	-37.04681		
17	6.601180639	170	-37.49403		
18	0.05972451	180	-37.5		
19	-6.481749965	190	-37.49445		
20	-13.01738333	200	-37.41089		
21	-19.51849065	210	-37.05746		
22	-25.91398485	220	-36.1462		
23	-32.07732264	230	-34.33774		
24	-37.82220211	240	-31.29586		
25	-42.90812388	250	-26.74481		
26	-47.05565829	260	-20.52203		
27	-49.96999518	270	-12.61931		
28	-51.37024597	280	-3.206806		
29	-51.02115595	290	7.363728		
30	-48.76347056	300	18.57759		
31	-44.5392353	310	29.7961		
32	14.3887	320	-38.40879536	320	40.31193
33	8.35024	330	-30.55714264	330	49.41477
34	3.81027	340	-21.28843183	340	56.46001
35	0.98187	350	-11.00881641	350	60.93272
36	0.00032	360	-0.19908116	360	62.49949

ROAD DIAGRAMM

SPEED DIAGRAM

TRAINING DIAGRAM

4. Before the start of construction, the graphics editor must be configured to work with parametric dependencies.

The construction will begin with the creation of a parametric model of the mechanism. In fig. 1 shows a drawing that was previously divided into seven fields. In the drawing field (1) we create a new view using the "Create View" command, and in the selected scale we depict the kinematic scheme of the mechanism in an arbitrary position.

Create a drawing layer for parameterizing objects. To do this, you can use the "Layer" button located in the current status bar. We create dimensions in the created layer (crank length, connecting rod and eccentricity). Then we activate the "Parameterization panel" with the "P" button on the "Toolbar". With the button "Fixsize" we will fix the values of affixed dimensions of the mechanism; if there is a need, we will correct them (the button "Set size value") and the button "Fix point" we will make a fixed axis of rotation of the crank. Turning to the main layer of the drawing, put down the size X_b, the angle of rotation of the crank q and the connecting rod γ.

Enter the variables: the coordinate of the point B along the axis OX - X_b and the angle of rotation of the crank - q. To do this, double-click with the left mouse button on the value of the corresponding size and in the dialog box that appears enter the designation of the variable.

Let's make additional constructions. Draw the trajectory of the point A of the crank and divide it into twelve equal parts. On the connecting rod, we fix the point S (the center of mass of the connecting rod) at a distance from the point A equal to, for example, half the length of the connecting rod [4].

Thus, the parametric model of the crank-slider mechanism is created. When you try to turn the crank around a fixed axis with the cursor, the whole mechanism will start moving without breaking the links imposed on its links. When the crank is stopped at an arbitrary position, the current scheme will display the current values of the parameters q, γ, X_b with the accuracy and units of measure specified in the settings of the graphic editor.

V.DISCUSSION

Through this model, both direct and inverse problems of geometric analysis can be solved, since the restructuring of the mechanism occurs when setting any of the above parameters, the other two are automatically calculated and their values are displayed on the diagram.

The plan of the positions of the mechanism is built in the field of the drawing (2) at the chosen scale by simply copying the links of the mechanism of the parametric model, sequentially installed in different positions along the marking of the trajectory of movement of the point A of the crank. Copying can be carried out as follows. Switch the "Toolbar" to the mode of editing objects with the "Editing Panel" button. Left-click on the crank to select it and on the connecting rod, together with Shift to add to the selected object. By pressing the "Copy" button on the toolbar, we will perform the above operation. If you use the "Bezier curve" button on the "Geometry toolbar" and successively connect a set of points S on the position plan, you can get the trajectory of the center of mass of the connecting rod [4].

In the drawing field (3) we plot the function of the position of the output link. To do this, in the selected scale, we construct a system of coordinate axes (q, X_b). Let us draw an auxiliary segment of arbitrary length parallel to the vertical axis, the lowest point of which will be fixed at the level of the origin. Let us write down the size of this segment, designate it with the new variable X_{b1} and associate it with the variable X_b. To do this, on the "Parameterization" toolbar, you must click the Equations button and in the dialog box that appears, enter the following line: $X_b = X_{b1}$. As a result, when the parametric model of the mechanism moves, the height of the auxiliary segment will change synchronously. Noting consistently the points of the vertex of this segment in the above-mentioned coordinate system (this can be done using the "Enter Point" and "Enter Auxiliary Horizontal Line" buttons on the "Geometry Toolbar" [7]), and then connecting them to a Bezier curve, we obtain a graph of the position function of the output link of the mechanism.

The velocity plan is built on the drawing field (4) at the selected scale. The constructions begin with the velocity vector of the point A of the crank, which, as is known, is equal in magnitude to the product of the crank length (L_1) and the angular velocity of its rotation (ω) and is directed in the direction of rotation of the crank perpendicular to the straight line O_1A.

Draw a segment of arbitrary length in an arbitrary direction. In the drawing layer for parameterization, set the length of this segment equal to the product $L_1 \omega$, make any of the extreme points of the segment fixed (velocity plan pole P_v), and set the direction — perpendicular to the crank of the parametric model of the mechanism, using the Perpendicular button of the Parameterization toolbar . The angular speed of rotation of the crank can be set equal to one, in this case, the plan of speeds will be identical to the plan of analogue speeds
.
Next, we graphically solve the well-known vector equation:
$V_b = V_a + V_{ba}$.
In the main drawing layer, in terms of velocities, from the extreme points of the vector V_a, we draw two arbitrary intersecting segments. Then we establish the connection of these segments with the parametric model of the mechanism.

The segment leaving the pole P_v(the velocity vector of point B - V_b) must be parallel to the line of motion of the slider, i.e. horizontal, and the second segment (relative velocity vector V_{ba}) is perpendicular to the connecting rod AB (the buttons "Horizontal" and "Perpendicular" of the "Parameterization" toolbar). Then we dimension the resulting P_{va} and P_{vb} segments and enter the variable V_{ba}[7].

Now, when the parametric model moves, the plan of the speeds of the mechanism will automatically change. When the crank is stopped at an arbitrary position, the current values of the speeds V_{ba} and V_b are displayed on the speed plan [5]. Moreover, the solution of the inverse problem of kinematic analysis is possible here. If the velocity value $V_b$is set on the velocity plane, then all related parametric models will be rearranged, i.e. the mechanism itself will take a position in which the speed of its output link corresponds to the given one.

The acceleration plan for a given mechanism is a graphical solution of the following vector equation:
$$W_b = W_a + W_{ba}^n + W_{ba}^t.$$
The acceleration plan is built on the drawing field (5) at the selected scale. Acceleration W_a is postponed from a fixed point - the poles (P_w) in the form of a segment of length $L_1 \cdot \omega^2$, which is parallel to the crank and directed from point A to point O_1 of the mechanism. Then it is necessary to build the acceleration W_{ban} in the form of a segment of length equal to V_{ba}^2 / L_2 (L_2 is the length of the connecting rod), which is parallel to the connecting rod and directed from point B to point A of the mechanism. To do this, we postpone a segment of arbitrary length from the end of the vector W_a, set the size, designate it with a new variable W, enter the equation $W = V_{ba}^2 / L_2$ and use the "Set parallelism" button to determine its position. From the end of the obtained vector, we draw a segment perpendicular to the connecting rod, before intersection with the segment drawn from the pole parallel to the line of motion of the slide. As a result of this construction, we obtain a parametric model of the acceleration plan, with which we can also solve the inverse problem.

VI. CONCLUSION

The task of the static calculation of mechanisms includes the definition of reactions in kinematic pairs and generalized driving forces. Static analysis of mechanisms is usually carried out on the basis of a static model that takes into account only the generalized driving forces Q, the forces of workloads P, and the reaction of connections R [1].

We attach the working load P = 100 N to the slider, and the generalized driving moment Q, balancing this load, to the crank. The mechanism is in balance, therefore, and each link is in balance. Consider a slider equilibrium. It is acted upon by three forces converging in the hinge B: the workload and two coupling reactions. To find the magnitude of the reactions using the equilibrium equation of the slide:

$$P + R_{03} + R_{23} = 0.$$

Plan the forces acting on the slider, build on the field of drawing (6). The scale value of the workload P is set aside from a fixed point - the pole (Pp). From the ends of this segment we draw two intersecting straight lines. One is perpendicular to the line of motion of the slider, the second is parallel to the connecting rod. We get a triangle of forces. We dimension the resulting segments, the lengths of which will be equal to the scale values of the reactions R_{03} and R_{23}.

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