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KINEMATIC TEST OF MECHANISMS

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In this paper, some single and multiple mechanisms having pivots and slides in the plain are analyzed. It has been demonstrated that using a computer program we can describe trajectories and velocity curves of any point of the mechanism, which are suitable for further investigations.

1. Introduction

One of the basic tasks of designing mechanisms is description of the actual position of a mechanism link with the help of driving parameters (displacement of the driven link and/or angle of rotation). Another basic task – the inverse kinematic one – is the opposite of the above, i.e. determination of possible values of the driving parameters (displacement and angle of rotation) for the given position of a point of the mechanism. The latter task has been reported on at the 27th Seminar of Machine Designers and Product Developers [6]. In this paper, some results from the background of this work will be presented, i.e. computer program related to the first task.

2. Basic terms related to mechanisms

Mechanisms contain kinematic chains [1], while these chains consist of links and joints. Links are rigid bodies. They are denoted by straight lines which connect joints on them. For example, if the links are connected by two joints, they are denoted by a straight line, if by three joints, they are denoted by a triangle. A joint can be a pivot, which allows for rotation of the connected links against each other around the pivot axis; or it can be a slide, which allows for displacement (slip) along the given line. Depending on the number of links, there are single-linked, double-linked, triple-linked, etc. kinematic chains.

3. The analytical method

The test of motion of mechanisms consisting of links connected by pivots and slides is carried out knowing some initial parameters. In the case of mechanism with one degree of freedom, the motion of the driven link is described as function of time $\boldsymbol{t}$ or of a geometric parameter proportional to time. The motion of the mechanism is studied in the

$$\boldsymbol{t}_1 \leq \boldsymbol{t} \leq \boldsymbol{t}_2$$

range.

By equidistant division of the above range, the actual position and velocity are determined at discrete time instances. The test precision can be increased by decreasing the scale division, i.e. by dividing the above range into more sections.

The positions of other links of the mechanism are determined for the position of the driven link at a given time instance. Knowing the two successive positions, the vector of displacement of an arbitrary point can be determined, out of which the average velocity can also be calculated. The instantaneous center curve and velocity curve are drawn in a similar way.

The determination of trajectory and instantaneous center curve leads towards elementary geometric constructions [2], [3]. The cross-points of circle and circle, circle and line, line and line should be determined; in other words, the desired points are determined by the ruler-and-compass construction. If the geometric task has several solutions, then, in order to determine the mechanism position for the given displacement of the driven link, further testing is required. It should be taken into consideration that the mechanism cannot be disassembled. For this reason, when determining a new position the previous state should be taken into account and a close to that solution should be chosen; if required, the scale division should be decreased.

In the case of mechanisms with several degrees of freedom the law of motion of all the driven links should be given.

Three-dimensional cases have also been considered, specifically, those pivot and slide mechanisms whose first kinematic chain consists of three links and its second and third joints must move within a plane. Other two-linked kinematic chains may connect to this. The importance of studying such type of mechanisms is discussed in [4].

4. The computer program

In order to carry out the above calculations and drawings, computer programs in **FORTRAN** and **C** programming languages were developed. In the former case the type of driving should be given as Function segments. The **FK(I)** segment gives displacement of the driven link in the case of rotation, while the **FE(I)** segment gives that in the case of linear motion; in our case in the

$$\boldsymbol{1} \leq \boldsymbol{I} \leq 50$$

range. In the case of mechanisms with two degrees of freedom, the motion of the other driven link is determined by segments **FK2 (I)** and **FE2 (I)**.

If interruption occurs when drawing the instantaneous center curve, and in case the curve falls outside the drawing area, the drawing is interrupted and resumed at the next point. Naturally, the scaling is set so that the whole mechanism fall within the diagram, only the points of the instantaneous center curve being too far from the mechanism are not drawn in order to facilitate evaluation of the diagram.

The program in **C** language creates data files, based on which the **KEYCREATOR** 3D mechanical design system carries out drawing. The ***mech0.cdl*** file in **CADL** programming language draws the mechanism using the ***mech1.dat*** and the ***mech2.dat*** data files. It denotes the tested points and their trajectories as well as draws the instantaneous center curve of bars containing those points, and creates a separate velocity curve.

This way one has numerical data and diagrams for an easier further analysis of the mechanism.

5. Example

Chosen different points of a triple-linked mechanism, the program draws trajectory of the point and, in another figure, its velocity curve or the hodograph. In this example, the instantaneous center curve is not denoted. Figures 1–4 present the analysis of two different points of the given mechanism. In the first case, the motion of the endpoint of a bar is studied (Figures 1–2); in the second case (Figures 3–4) the center of the bar connected to another bar is chosen.

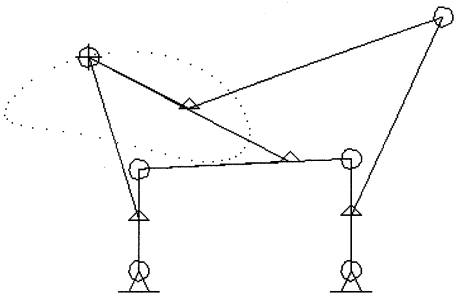


Figure 1: Trajectory of a point of the mechanism

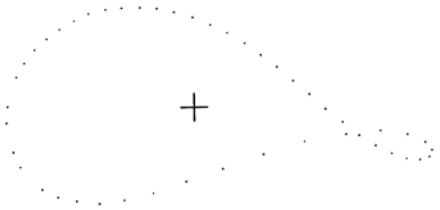


Figure 2: Velocity curve of a point of the mechanism

The pivots are denoted by empty circles. The joint between intermediate point of the bar and a pivot is denoted by triangles. The velocity curve of the given point is shown next to the mechanism. A plus sign shows the point whose trajectory is calculated and positions corresponding to the discrete displacement of the driven link are denoted. The distance measured between the positions shows the value of velocity. The farther the two successive positions are from each other, the higher is the velocity of the point. The velocity curve shows the variation of velocity more illustratively.

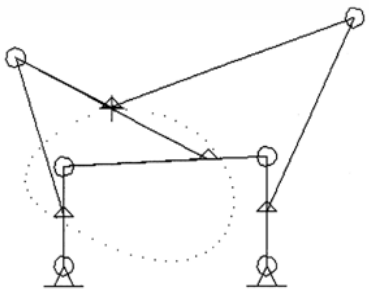


Figure 3: Trajectory of another point of the mechanism

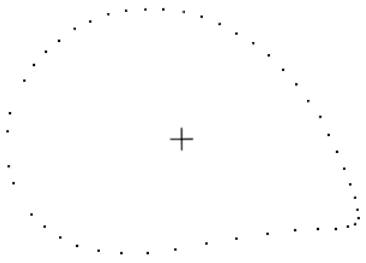


Figure 4: Velocity curve of another point of the mechanism

6. The inverse kinematic task

The other task is to determine possible values of the driving parameters (displacement and angle of rotation) for the given position of a point of the mechanism, for example, by methods of algebraic geometry. Such a task was solved in [5, 6] for open chained mechanisms, in other words, robots (Figure 5).

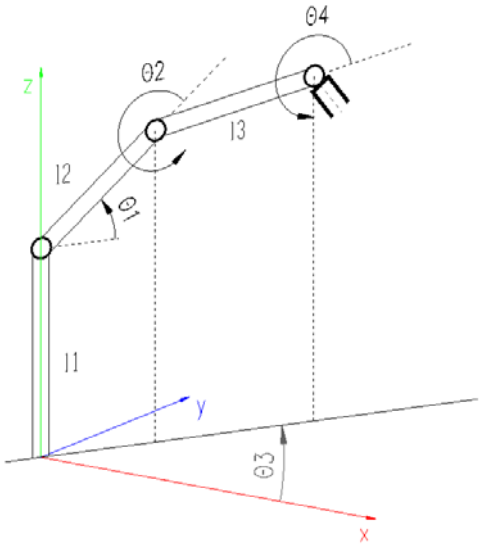


Figure 5: Spatial location of the robot [5]

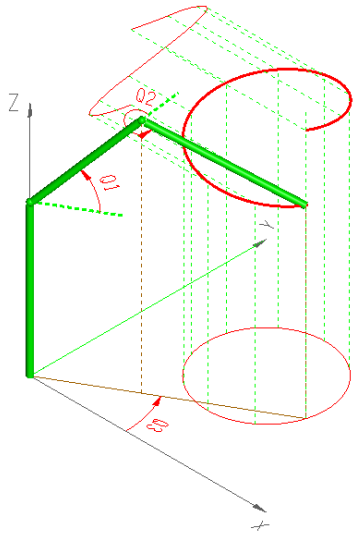


Figure 6: Structure moving along trajectory prescribed by its endpoint [5]

In the following task, the motion of the robot along a specific trajectory was studied; the calculations were performed with the help of MAPLE16 software, while the actual positions were drawn by KEYCREATOR software (Figure 6, 7).

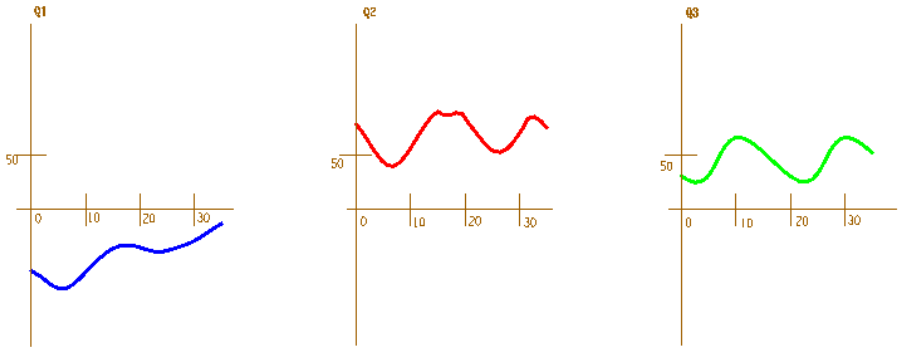


Figure 7: The variation of the angles of structure

7. Summary

A computer program has been developed for the case of planar pivot and slide mechanisms, which is suitable for the determination of position and velocity state on the basis of kinematic analysis of the law of motion of the driven link. More specifically, the program determines the position of an arbitrary point, that of the instantaneous center of velocity of an arbitrary link and then draws trajectories, instantaneous center curves and velocity curves as function of a geometric parameter proportional to time. In the case of rotation, the program examines whether the driven link is rotatable or not.

Another program solves the opposite task, i.e. determines the driving parameters of motion along a pre-defined trajectory.

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