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RESEARCH ON THE KINEMATICS OF A MECHANISM WITH A TRIAD AS A COMPONENT

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ABSTRACT

The structural approach to mechanisms from the perspective of component kinematic groups shows that as the class of component groups increases, the complexity of the mechanisms that contain them also increases. From this perspective, it is obvious that solving problems related to the kinematics of these mechanisms also becomes much more difficult to put into practice. In such cases, when mechanisms contain kinematic groups of a class greater than two, determining the analytical expressions of the parameters that establish the configuration of the mechanism during operation is extremely difficult. Therefore, in such cases, the development of some numerical calculation algorithms is indicated. The present paper analyzes the operation of a mechanism that has a triad as a component, in which one of the component kinematic joint is translational. To determine the variation of the position parameters, an iterative numerical calculation algorithm was developed and transposed into a computer program that allows the simulation of the functioning of the analyzed mechanism. Finally, the variation curves of these parameters over a kinematic cycle are presented, for a working configuration of the analyzed mechanism.

Keywords: mechanism, kinematic group, triad, position parameters, working configuration

INTRODUCTION

The analysis of mechanisms from a structural and kinematic point of view is a necessary step in evaluating their correct functioning [1-10]. From a structural point of view, it is known that with the increase in the class of component kinematic groups, the complexity of the methods used for their analysis also increases [11-16]. In addition, with the increase in the class of mechanisms, the possible number of their working configurations also increases. Also, in the case of these mechanisms, the variation over the kinematic cycle of operation of the parameters that define the topological configuration of the studied mechanism must be studied very carefully in order to highlight possible problems related to the dimensions of the component elements that may lead to the impossibility of the mechanism functioning in certain portions of the cycle [17-25].

This paper analyzes the operation of a mechanism of the third class that has a triad as a component, in which one of the component kinematic joint is translational. To determine the variation over the kinematic cycle of operation of the position parameters, an iterative numerical calculation algorithm was developed and transposed into a computer simulator using Maple program [26]. Finally, the variation curves of these parameters over a kinematic cycle are presented, for a working configuration of the analyzed mechanism. The iterative numerical method used for kinematic analysis and the operating simulator developed by the author has a novelty character, offering the possibility to intervene quickly and effectively on the dimensions of the component elements to improve the functioning of the analyzed mechanism.

MATERIALS AND METHODS

In figure 1 is presented a plane mechanism whose degree of mobility is equal to one. Figure 2 shows the structural diagram of the mechanism from which the *2-3-4-5* component triad can be observed.

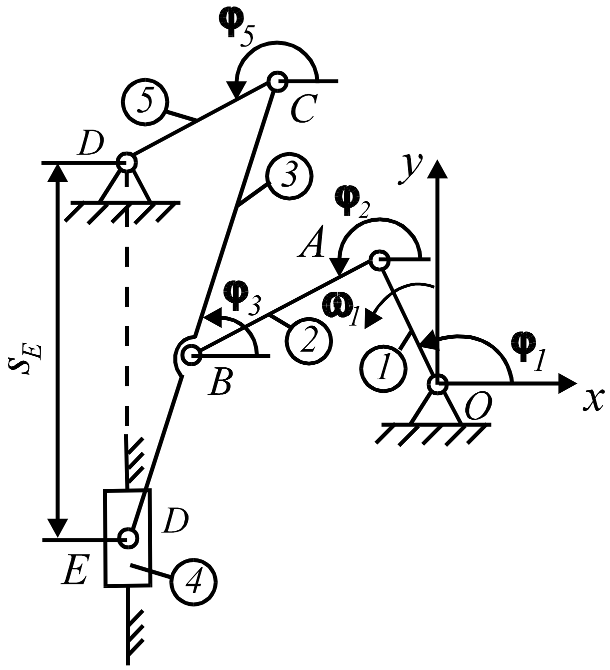

Figure 1. *Plane mechanism with the degree of mobility equal to one*

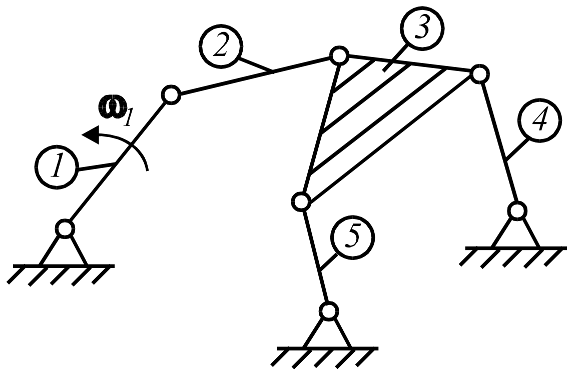

Figure 2. *Structural diagram of the mechanism in figure 1*

Figure 3 shows the graph associated with the mechanism in figure 1. As can be seen from figure 3, the mechanism consists of two independent contours: *0-1-3-5-0* and *0-5-3-4-0*.

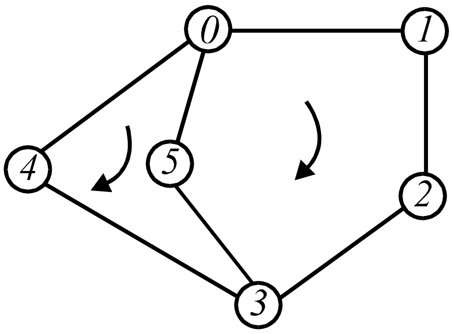

Figure 3. *The graph associated with the mechanism in figure 1*

The closing vector equations corresponding to the two contours are as follows:

$$\begin{cases} \overrightarrow{OA}+\overrightarrow{AB}+\overrightarrow{BC}+\overrightarrow{CD}+\overrightarrow{DO}=0 \\ \overrightarrow{DC}+\overrightarrow{CE}+\overrightarrow{ED}=0 \end{cases} \quad (1)$$

By projecting these equations onto the axes of the (Oxy) coordinate system (figure 1), the following systems of equations are obtained:

$$\begin{cases} l_1\cdot\cos\varphi_1+l_2\cdot\cos\varphi_2+l_{31}\cdot\cos\varphi_3+l_5\cdot\cos\varphi_5+|x_D|=0 \\ l_1\cdot\sin\varphi_1+l_2\cdot\sin\varphi_2+l_{31}\cdot\sin\varphi_3+l_5\cdot\sin\varphi_5-y_D=0 \end{cases} \quad (2)$$

$$\begin{cases} l_5\cdot\cos(\varphi_5-\pi)+l_3\cdot\cos(\varphi_3+\pi)=0 \\ l_5\cdot\sin(\varphi_5-\pi)+l_3\cdot\sin(\varphi_3+\pi)+s_E=0 \end{cases} \quad (3)$$

where: $l_1=OA$; $l_2=AB$; $l_{31}=BC$; $l_3=CE$; $l_5=CD$.

Analytical solution of the systems of equations (2) and (3) for determining the expressions of the position parameters: φ_2, φ_3, φ_5 and s_E as a function of the motor angle φ_1 is very difficult to obtain. Therefore, a numerical approach was used as will be detailed below.

RESULTS AND DISCUSSIONS

For analyzing the functioning of the mechanism a simulator was developed by the author in Maple program. Simulations were performed with the following values: $l_1=0.15$ m; $l_2=0.7$ m; $l_3=1$ m; $l_{31}=0.25$ m; $l_5=0.4$ m; $x_D=-0.45$ m and $y_D=0.5$ m.

First, the values of the position parameters: φ_2, φ_3, φ_5 and s_E were determined considering a starting position corresponding to the motor angle $\varphi_1=0$. The solution of the systems of equations (2) and (3) was achieved in this case using the Maple *fsolve* function, in which the following initial values of the position parameters used by the *fsolve* function solver were introduced: $\varphi_2 = 2\,\text{rad}$, $\varphi_3 = 1\,\text{rad}$, $\varphi_5 = -2.2\,\text{rad}$ and $s_E = 0.6\,\text{m}$.

The following values for the position parameters corresponding to $\varphi_1 = 0$ were thus obtained: $\varphi_2 = 2.196\,\text{rad}$; $\varphi_3 = 1.314\,\text{rad}$; $\varphi_5 = -2.257\,\text{rad}$ and $s_E = 0.658\,\text{m}$.

The values of these parameters were then obtained iteratively using the *fsolve* function, in which the values of the parameters obtained in the previous step were entered as initial values used by its solver.

Figures 4, 5, 6 and 7 present the variation curves over a kinematic operating cycle for: φ_2, φ_3, φ_5 and s_E.

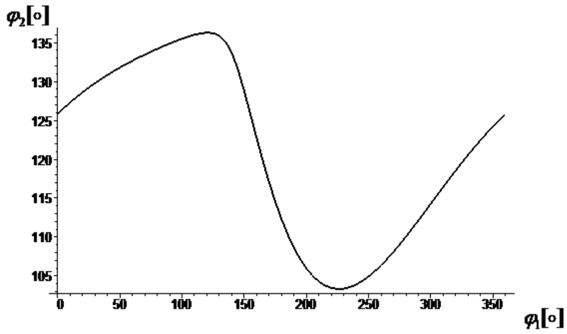

Figure 4. *The variation curve over a kinematic operating cycle for* φ_2

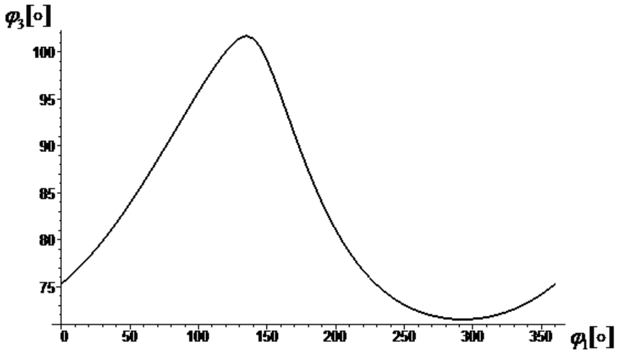

Figure 5. *The variation curve over a kinematic operating cycle for* φ_3

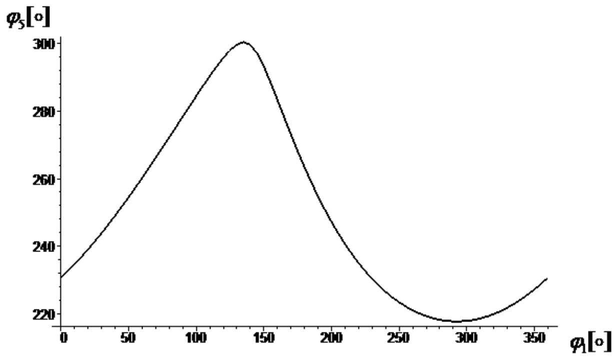

Figure 6. *The variation curve over a kinematic operating cycle for* φ_5

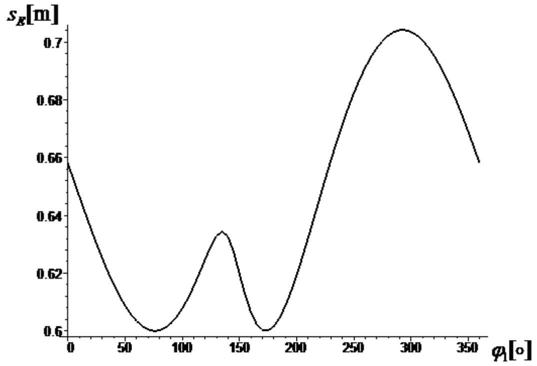

Figure 7. *The variation curve over a kinematic operating cycle for* s_E

Figures 8, 9, 10 and 11 present the variation curves over a kinematic operating cycle for the speeds: ω_2, ω_3, ω_5 and v_E. They were determined with the relationships:

$$\begin{cases} \omega_i = \dfrac{\Delta\varphi_i}{\Delta\varphi_1}\cdot\omega_1; \quad i = 2,3,5 \\ v_E = -\dfrac{\Delta s_E}{\Delta\varphi_1}\cdot\omega_1 \end{cases} \tag{4}$$

where: $\Delta\varphi_i$, for $i = 2,3,5$, represents the difference between two consecutive values of the angle φ_i established within the iterative calculation algorithm; analogously, Δs_E represents the difference between two consecutive values of the displacement s_E; the difference $\Delta\varphi_1$ between two consecutive values of the motor angle φ_1 was chosen equal to 5°; ω_1 is the angular speed of the motor element *1* that was chosen equal to 10 rad/s.

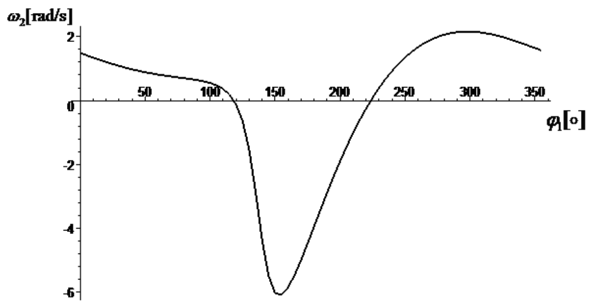

Figure 8. *The variation curve over a kinematic operating cycle for* ω_2

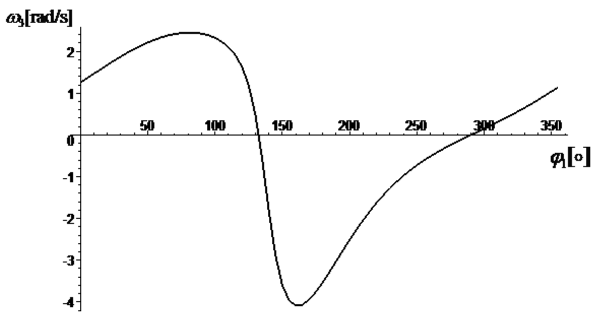

Figure 9. *The variation curve over a kinematic operating cycle for* ω_3

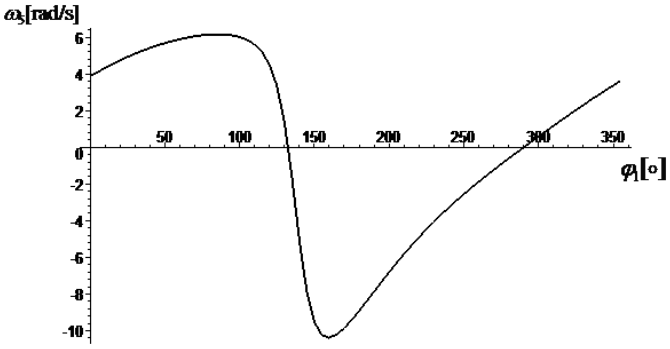

Figure 10. *The variation curve over a kinematic operating cycle for* ω_5

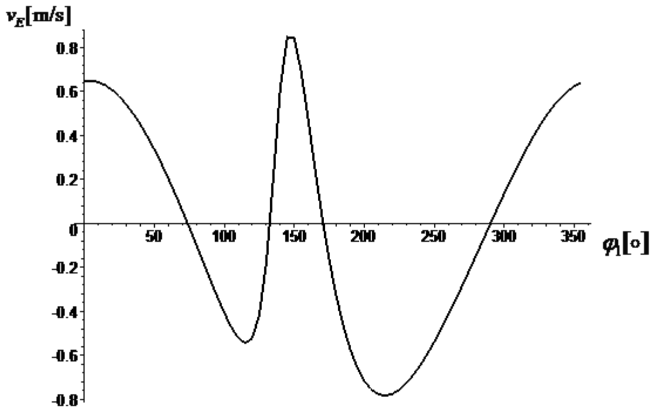

Figure 11. *The variation curve over a kinematic operating cycle for* v_E

The variation curves on the kinematic operating cycle of the analyzed mechanism by their continuity demonstrate that there are no problems regarding the functioning of the mechanism. Also, the values of the angular velocities corresponding to the component elements are within acceptable limits, comparable to the angular velocity of the motor element. It can be concluded that the obtained results demonstrate the effectiveness of the analysis algorithm used and of the simulator developed based on it.

CONCLUSIONS

It is well known that the analysis of mechanisms from a kinematic point of view is necessary in evaluating their correct functioning and that, from a structural point of view, with the increase in the class of component kinematic groups, the complexity of the methods used for their analysis also increases. In the paper was analyzed the operation of a mechanism of the third class that has a triad as a component, in which one of the component kinematic joint is translational. The variations over the kinematic cycle of operation of the position parameters which characterizes the working configuration of the mechanism have been established using an iterative numerical calculation algorithm that was developed and transposed by the author into a computer simulator using Maple program. The variation curves of these parameters over a kinematic cycle were presented for a working configuration of the analyzed mechanism.

The operating simulator offers the possibility to intervene quickly and effectively on the dimensions of the component elements to improve the functioning of the analyzed mechanism. The results obtained with the simulator demonstrate by their continuity that there are no problems regarding the functioning of the mechanism, so it is demonstrated in this way the effectiveness of the analysis algorithm used and of the simulator developed based on it.

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