STUDY OF THE LOAD ON KINEMATIC PAIRS OF A FOUR-BAR LINKAGE MECHANISM

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Annotation. This article presents a comprehensive study on the load distribution in kinematic pairs of a four-bar linkage mechanism, which is widely used in various mechanical systems due to its simple structure and reliable motion transmission. The research focuses on analyzing the internal forces and moments acting on each link and joint under different loading conditions. Through analytical modeling and computer-aided simulation, the influence of input torque and external resistance on the force transmission efficiency and wear characteristics of the kinematic pairs is evaluated. The findings provide important insights into optimizing the design parameters of four-bar mechanisms for improved performance, durability, and load-bearing capacity in engineering applications.

Keywords. Four-bar linkage mechanism, kinematic pair, load distribution, force analysis, mechanical system, joint stress, input torque, simulation, wear resistance, optimization.

Modern technological machines widely use four-bar linkage mechanisms. Determining the reactions in the kinematic pairs of these mechanisms is an important factor in their design. For the rational design of a four-bar linkage, it is advisable to use an analytical method based on d'Alembert's principle. In this case, the equilibrium of individual Assur groups must be considered by formulating equilibrium equations for each link of the mechanism.

Fig. 1 shows the calculation diagram of a four-bar linkage mechanism with applied known forces and moments.

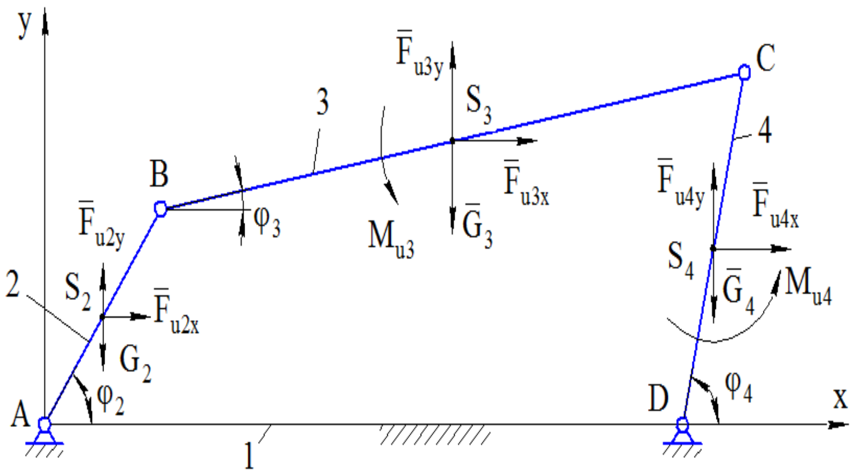

Fig. 1. Forces acting on the links of a four-bar linkage mechanism

Where: $\overline{G}_2$ - is the gravitational force of the crank applied at the center of mass S_2, $\overline{F}_{u2}$ is the inertial force of the crank applied at point S_2, $\overline{G}_3$ - is the gravitational force of the connecting rod applied at its center of mass, M_{u3}-is the moment of inertial forces of the connecting rod, $\overline{F}_{u3X}$ and $\overline{F}_{u3Y}$-are the components of the inertial force of the connecting rod, $\overline{G}_4$ - is the gravitational force of the rocker applied at its center of mass S_4, M_{u4}-is the moment of inertial forces of the rocker, $\overline{F}_{u4X}$ and $\overline{F}_{u4Y}$ - are the components of the inertial force of the rocker applied at its center of mass S_4. M_{C4}-is the moment of technological resistance forces acting on the rocker.

The system of algebraic equations describing the equilibrium conditions of the links of the four-bar linkage mechanism can be represented as follows:

$$\Sigma X = 0 \qquad \overline{R}_{CX} + \overline{F}_{u4X} + \overline{R}_{DX} = 0$$

$$\Sigma Y = 0 \qquad \overline{R}_{CY} + \overline{F}_{u4Y} - \overline{G}_4 + \overline{R}_{DY} = 0$$

$$\Sigma M_{S4} = 0 \qquad \overline{R}_{CY} \cdot l_{CS4} \cdot \cos\varphi 4 + \overline{R}_{DX} \cdot l_{DS4} \cdot \sin\varphi 4 + M_{C4} - \overline{R}_{CX} \cdot l_{CS4} \cdot \sin\varphi 4 - \overline{R}_{DY} \cdot l_{DS4} \cdot \cos\varphi 4 + M_{u4} = 0$$

$$\Sigma X = 0 \qquad \overline{R}_{BX} + \overline{F}_{u3X} - \overline{R}_{CX} = 0$$

$$\Sigma Y = 0 \qquad \overline{R}_{BY} + \overline{F}_{u3Y} - \overline{G}_3 - \overline{R}_{CY} = 0$$

$$\Sigma M_{S3} = 0 \qquad -\overline{R}_{BY} \cdot l_{BS3} \cdot \cos\varphi 3 - \overline{R}_{CY} \cdot l_{CS3} \cdot \cos\varphi 3 + \overline{R}_{BX} \cdot l_{BS3} \cdot \sin\varphi 3 - \overline{R}_{CX} \cdot l_{CS3} \cdot \sin\varphi 3 + M_{u3} = 0$$

$$\Sigma X = 0 \qquad \overline{R}_{AX} - \overline{R}_{BX} + \overline{F}_{u2X} = 0$$

$$\Sigma Y = 0 \qquad \overline{R}_{AY} - \overline{R}_{BY} + \overline{F}_{u2Y} - \overline{G}_2 = 0$$

$$\Sigma M_A = 0 \quad \overline{R}_{BX} \cdot l_2 \cdot \sin\varphi 2 - \overline{R}_{BY} \cdot l_2 \cos\varphi 2 - \overline{G}_2 \cdot l_{AS2} \cdot \cos\varphi 2 + M_Y = 0$$

Where: $\overline{R}_{CX}$, $\overline{R}_{DX}$, $\overline{R}_{CY}$ и $\overline{R}_{DY}$ are the components of reaction forces in hinges “C” and “D”. The total reactions in hinges “C” and "D" are equal to $\overline{R}_C = \overline{R}_{CX} + \overline{R}_{CY}$, $\overline{R}_D = \overline{R}_{DX} + \overline{R}_{DY}$; respectively. φ_4- is the rotation angle of the rocker l_{DS4}-is the position of the rocker's center of mass, $l_{DS4} = l_{DC}/2$; $\overline{R}_{BX}$, $\overline{R}_{BY}$, $\overline{R}_{AX}$ и $\overline{R}_{AY}$-are the components of reaction forces in hinges “A” and “B”, l_{BS3}-is the position of the connecting rod's center of mass, $l_{BS3} = l_{BC}/2$; φ_3-is the rotation angle of the connecting rod, φ_2-is the rotation angle of the crank, l_{AS2}-is the position of the crank’s center of mass, $l_{AS2} = l_{AB}/2$; M_Y - is the balancing moment.

The system of equations (1) was solved on a computer using MathCAD 15. The results of the calculations provided the patterns of changes in the reactions in the kinematic pairs “A”, “B”, “C”, "D" and the balancing moment M_y on the crank shaft.

To study the influence of the mechanism's parameters on the load of the kinematic pairs, the reactions were determined by varying:

The weight of the rocker from 20 to 100 N in steps of 20 N, the angular velocity of the crank from 10 to 50 c^{-1} in steps of 10 c^{-1}, The moment of technological resistance forces acting on the rocker from 80 to 160 Nm in steps of 20 Nm.

The results of the computer calculations revealed:

1. The weight of the rocker does not significantly affect the reactions in the kinematic pairs of the mechanism. For example, at $G_4 = 20H$, the maximum reactions in the hinges are $R_{Bmax} = 688$ N, $R_{Cmax} = 527$ N, $R_{Dmax} = 254$N;
2. The moment of technological resistance foces M_C, has the greatest influence on the reactions in the kinematic pairs. For example, at M_C=80, Nm, the reactions are $R_{B\max}$=841 N, $R_{C\max}$=689 N, R_{Dmax}=627N while at M_C=160 Nm, they increase to $R_{B\max}$=1471 N, $R_{C\max}$=1338 N, R_{Dmax}=1278N.

The developed mathematical models for the kinetostatic analysis of the four-bar linkage mechanism and the computer programs for their implementation allow for the determination of rational dynamic parameters of the mechanism during its design stage.

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