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On the Calculus of the Necessary Motor Moment for the Running of the Plane Mechanisms

Dorin Bădoiu

Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti 39, Ploieşti
e-mail: badoiu@upg-ploiesti.ro

Abstract

In this paper a method for the dynamic analysis of plane mechanisms with a single degree of freedom is presented. The main purpose is to determine the motor moment which is necessary for their running. The motor moments are calculated using the variation of the equilibrium moment on a cinematic cycle. With this end in view, a simulation program has been developed. Finally, some simulation results are presented.

Key words: *mechanism, joints, motor moment, equilibrium moment*

Introduction

An optimum design of the mechanisms demands that the motor moments which are necessary for their running be calculated rigorously. In this paper a methodology for the dynamic analysis of plane mechanisms with a single degree of freedom is presented. The main purpose of this method is to calculate the motor moments which are necessary for the running in good conditions of these mechanisms. The motor moments are calculated using the variation of the equilibrium moment on a cinematic cycle. The method is applied in the case of a plane mechanism with two independent contours. A simulation program has been developed. Finally, some simulation results are presented.

Theoretical Considerations and Simulation Results

For a plane mechanism with a single degree of freedom, the variation of the equilibrium moment M_e on a cinematic cycle can be calculated with the following relation [2]:

$$M_e = -\frac{1}{\omega_1} \cdot \left(\sum_j \left(\overline{F}_j \cdot \overline{v}_j + \overline{M}_j \cdot \overline{\omega}_j \right) + \sum_j \left(\overline{F}_{ij} \cdot \overline{v}_j + \overline{M}_{ij} \cdot \overline{\omega}_j \right) \right) \tag{1}$$

where: $\overline{F}_j$ and $\overline{M}_j$ are the resultant force and the resultant moment corresponding to the external forces and moments which act on the *j* link and which are reduced in the mass centre of the *j* link, $\overline{F}_{ij}$ and $\overline{M}_{ij}$ are the resultant inertia force and the resultant inertia moment corresponding to the j link, $\bar{v}_j$ is the speed of the mass centre of the j link, $\bar{\omega}_j$ is the angular speed of the j link.

For calculating the resultant inertia forces, the resultant inertia moments, the speeds of the mass centers of the links and the angular speeds of the links, the cinematic analysis of the mechanism has to be accomplished. With this end in view, some analytical methods [1] can be applied: the method of the projection of the independent vector circuits, the method of the independent cycles, the method of the transfer function etc.

When the variation of the equilibrium moment on a cinematic cycle has been determined, the motor moment M_m which is necessary for the running in good conditions of the mechanism can be calculated with the following relation [2]:

$$M_m = \frac{\int_{\Phi c} M_e(\varphi_1)\,\mathrm{d}\varphi_1}{\Phi_c} \tag{2}$$

where: Φ_c is the angular value corresponding to the cinematic cycle (for the most working mechanisms $\Phi_c = 2\pi$) and φ_1 is the crank angle corresponding to the motor element of the mechanism.

The method has been applied for the plane mechanism represented in figure 1.

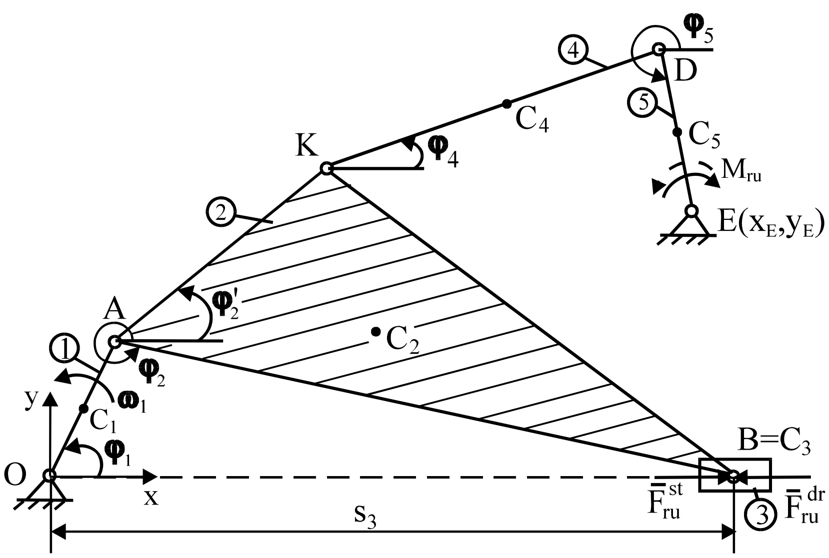

Fig. 1. Plane mechanism with two independent contours

For this mechanism the following elements are considered to be known:

- the dimensions of the component links: *OA*=0.06m; *AB*=0.3m; *AK*=0.1m; *BK*=0.24m; *KD*=0.24m; *DE*=0,1m; $x_E = 0.2\text{m}$; $y_E = 0.06\text{m}$. The mass centers: C_1, C_4, C_5 are on the middle of the corresponding links and C_2 is on the mass center of the triangle *ABK*;
- the mass of the component links: $m_1 = 1.5\text{kg}$; $m_2 = 7\text{kg}$; $m_3 = 2\text{kg}$; $m_4 = 5.5\text{kg}$; $m_5 = 3\text{kg}$;
- the moments of inertia of the links: $I_{C_1} = 0.003\ \text{kgm}^2$; $I_{C_2} = 0.35\ \text{kgm}^2$; $I_{C_4} = 0.12\ \text{kgm}^2$; $I_{C_5} = 0.03\ \text{kgm}^2$. The value of I_{C_3} is neglected;

- the technological forces and moments: $F_{ru}^{dr} = 1000\ \text{N}$; $F_{ru}^{st} = 100\ \text{N}$; $M_{ru} = 120\ \text{Nm}$;
- the nominal angular speed of the motor link of the mechanism: $\omega_1 = 10\ \text{rad/s}$.

The method of the projection of the independent vector circuits [1] has been used for the positional and cinematic analysis. The mechanism has two independent contours: $O-A-B-O$ and $O-A-K-D-E-O$. By projecting the vector circuits corresponding to these independent contours on the *x* and *y* axes (fig. 1), the following systems of equations are obtained:

$$\begin{cases} OA\cdot\cos\varphi_1 + AB\cdot\cos\varphi_2 - s_3 = 0 \\ OA\cdot\sin\varphi_1 + AB\cdot\sin\varphi_2 = 0 \end{cases} \tag{3}$$

$$\begin{cases} OA\cdot\cos\varphi_1 + AK\cdot\cos\varphi_2' + KD\cdot\cos\varphi_4 + DE\cdot\cos\varphi_5 - x_E = 0 \\ OA\cdot\sin\varphi_1 + AK\cdot\sin\varphi_2' + KD\cdot\sin\varphi_4 + DE\cdot\sin\varphi_5 - y_E = 0 \end{cases} \tag{4}$$

where: $\varphi_2' = \varphi_2 - 2\pi + \angle KAB$.

By solving the systems of equations (3) and (4), the unknown parameters: $\varphi_2, s_3, \varphi_4$ and φ_5 can be calculated from the following relations:

$$\begin{cases} \sin\varphi_2 = -\dfrac{OA}{AB}\cdot\sin\varphi_1 \\ s_3 = OA\cdot\cos\varphi_1 + \sqrt{AB^2 - OA^2\cdot\sin^2\varphi_1} \\ A_4\cdot\cos\varphi_4 + B_4\cdot\sin\varphi_4 = C_4 \\ \varphi_5 = ATAN2(B_5, A_5) \end{cases} \tag{5}$$

where:

$$\begin{cases} A_4 = 2\cdot OA\cdot KD\cdot\cos\varphi_1 + 2\cdot AK\cdot KD\cdot\cos\varphi_2' - 2\cdot x_E\cdot KD \\ B_4 = 2\cdot OA\cdot KD\cdot\sin\varphi_1 + 2\cdot AK\cdot KD\cdot\sin\varphi_2' - 2\cdot y_E\cdot KD \\ C_4 = DE^2 - OA^2 - AK^2 - KD^2 - x_E^2 - y_E^2 - 2\cdot OA\cdot AK\cdot\cos\varphi_1\cdot\cos\varphi_2' - \\ \quad - 2\cdot OA\cdot AK\cdot\sin\varphi_1\cdot\sin\varphi_2' + 2\cdot x_E\cdot(OA\cdot\cos\varphi_1 + AK\cdot\cos\varphi_2') + \\ \quad + 2\cdot y_E\cdot(OA\cdot\sin\varphi_1 + AK\cdot\sin\varphi_2') \end{cases} \tag{6}$$

$$\begin{cases} A_5 = -\dfrac{1}{DE}\cdot(OA\cdot\cos\varphi_1 + AK\cdot\cos\varphi_2' + KD\cdot\cos\varphi_4 - x_E) \\ B_5 = -\dfrac{1}{DE}\cdot(OA\cdot\sin\varphi_1 + AK\cdot\sin\varphi_2' + KD\cdot\sin\varphi_4 - y_E) \end{cases} \tag{7}$$

and the function $ATAN2(B_5, A_5)$ calculates $arctg(B_5/A_5)$ by taking into account the signs of A_5 and B_5.

The angular and linear speed and accelerations distributions have been determined by deriving with respect to time the variation functions of the corresponding position parameters. Then, the variation of the equilibrium moment M_e has been obtained using the relation (1).

The analysis has been transposed into a computer program. In the figure 2 the variation of the equilibrium moment M_e is presented. Then, by applying the relation (2) the value of the necessary motor moment has been calculated: $M_m = 89.117$ Nm.

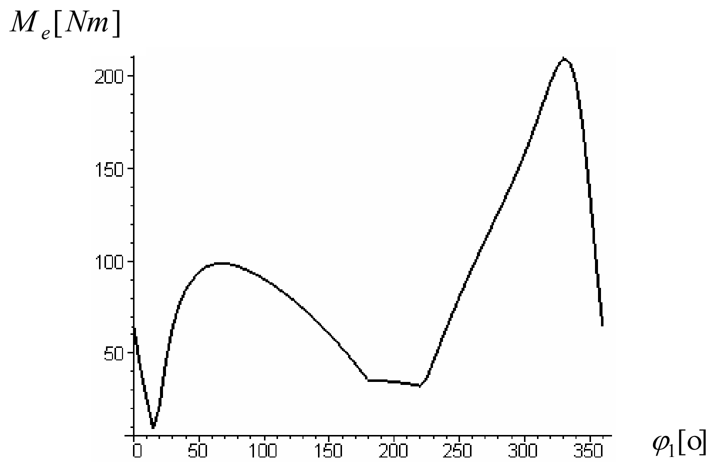

Fig. 2. The variation of the equilibrium moment

Conclusions

In this paper a method for calculating the motor moments which are necessary for the running in good conditions of the mechanisms with a single degree of freedom is presented. The motor moments are calculated using the variation of the equilibrium moment on a cinematic cycle. The method is applied in the case of a plane mechanism with two independent contours. A simulation program has been developed. This computer program can then be used for optimum design of the analyzed mechanism.

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Asupra calculului momentului motor necesar pentru funcționarea mecanismelor plane

Rezumat

În articol se prezintă o metodă de analiză dinamică a mecanismelor plane cu un singur grad de libertate. Scopul principal este de a determina momentul motor necesar pentru acționarea lor. Momentele motoare sunt calculate folosind variatia momentului de echilibrare pe un ciclu cinematic. În acest scop s-a dezvoltat un program de calculator. În final, sunt prezentate o serie de rezultate ale simulărilor.