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Research Concerning the Variation of the Motor Moment in the Case of a Plane Mechanism

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Abstract

In this paper the variation of the motor moment in the case of a plane mechanism is analyzed. The motor moment is calculated using the reduced moment corresponding to the technological forces and moments that work on the component links of the mechanism. The technological forces vary proportionally with the speed of the links on which they work. A computer program that simulates the mechanism functioning has been developed.

Key words: *mechanism, dynamic analysis, motor moment.*

Introduction

One of the most important problems that must to be solved in mechanisms designing is to determine the value of the motor moment for a proper functioning. In this scope, the achievement of computer simulation programs that permit establishing the variation of different cinematic and dynamic parameters is necessary.

In this paper the variation of the motor moment in the case of a plane mechanism is analyzed. The motor moment is calculated using the reduced moment corresponding to the technological forces and moments that work on the component links of the mechanism. The technological forces vary proportionally with the speed of the links on which they work. A computer program that simulates the mechanism functioning has been developed. This computer program has been used to analyze the variation of the necessary motor moment.

Theoretical Considerations and Verification Results

In figure 1 the mechanism that will be analyzed is presented. The following elements are considered to be known:

- the dimensions of the component links: *OA*=0.06m; *AB*=0.45m; *BC*=*BD*=*CD*=0.3m; *DE*=0.75m; *MC*=0.1m. The mass centers: C_1, C_2, C_4 are on the middle of the corresponding links and C_3 is on the mass centre of the triangle *BCD*. For the analysis *OC* varies between 0.48m and 0.64m;
- the mass of the component links: $m_1 = 1{,}5\text{kg}$; $m_2 = 7\text{kg}$; $m_3 = 9\text{kg}$; $m_4 = 12\text{kg}$; $m_5 = 2\text{kg}$;

- the moments of inertia of the links: $I_{C_1} = 0{,}001\ \text{kgm}^2$; $I_{C_2} = 0{,}12\ \text{kgm}^2$; $I_{C_3} = 0{,}25\ \text{kgm}^2$; $I_{C_4} = 0{,}56\ \text{kgm}^2$. The value of I_{C_5} is neglected;
- the technological forces working on the link *5* vary proportionally with the speed of this link: $F_{ru}^{dr} = k_{f_{ru}^{dr}} \cdot v_5$; $F_{ru}^{st} = k_{f_{ru}^{st}} \cdot v_5$. The coefficient $k_{f_{ru}^{dr}}$ varies between 1500 $\frac{\text{N}\cdot\text{s}}{\text{m}}$ and 3000 $\frac{\text{N}\cdot\text{s}}{\text{m}}$, and the coefficient $k_{f_{ru}^{st}}$ varies between 150 $\frac{\text{N}\cdot\text{s}}{\text{m}}$ and 300 $\frac{\text{N}\cdot\text{s}}{\text{m}}$;
- the technological moment M_{ru}, working on the link *3,* varies between 120 Nm and 180Nm;
- the nominal angular speed of the leader link of the mechanism: $\omega_1 = 10\text{rad/s}$.

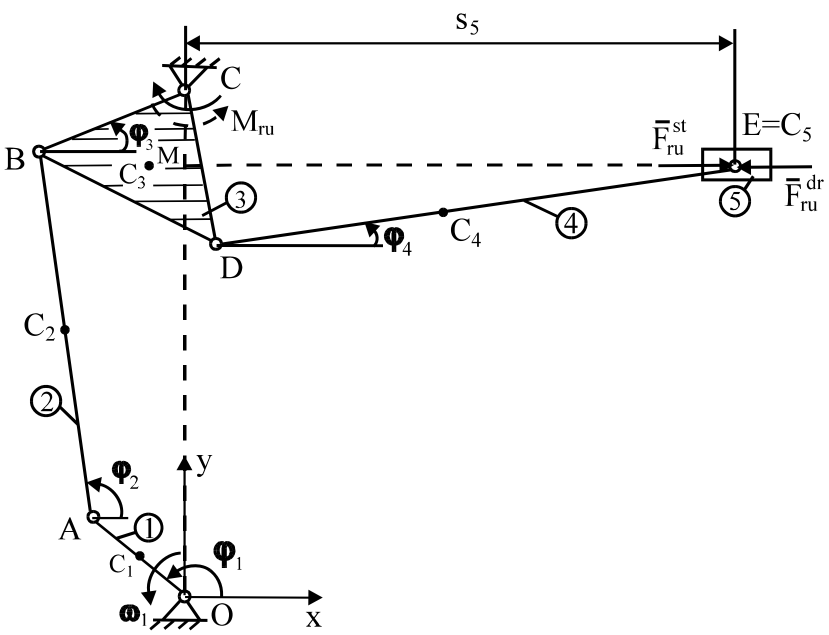

Fig. 1. Plane mechanism

The motor moment M_m, necessary for a proper functioning of the mechanism, is calculated using the variation on a cinematic cycle ($\Phi_c = 2\pi$) of the reduced moment M_{red}^{ru}, corresponding to the technological forces and moments that work on the links *3* and *5*, with the following relation [2]:

$$M_m = \frac{\int_{\Phi_c} \left| M_{red}^{ru}(\varphi_1) \right| \mathrm{d}\varphi_1}{\Phi_c} \tag{1}$$

where: the module of the reduced moment $\left| M_{red}^{ru} \right|$ can be determined with the relation [2]:

$$\left| M_{red}^{ru} \right| = \frac{1}{\omega_1} \cdot \left(\left| \overline{F}_{ru} \cdot \overline{v}_5 \right| + \left| \overline{M}_{ru} \cdot \overline{\omega}_3 \right| \right) \tag{2}$$

where: $\overline{F}_{ru}$ is equal to the technological force $\overline{F}_{ru}^{dr}$ when the speed of link *5* is positive ($v_5 > 0$) and is equal to $\overline{F}_{ru}^{st}$ when $v_5 < 0$; $\overline{\omega}_3$ is the angular speed of the link *3*.

For obtaining the variation of the reduced moment M_{red}^{ru}, the positional and cinematic analysis of the mechanism has been accomplished. The method of the projection of the independent vector circuits has been used for the positional analysis [1]. The mechanism has two independent contours: $O-A-B-C-O$ and $C-D-E-C$.

The unknown parameters: $\varphi_2, \varphi_3, \varphi_4$ and s_5 (fig. 1) can be calculated from the following relations [3]:

$$A_2 \cdot \cos\varphi_2 + B_2 \cdot \sin\varphi_2 = C_2 \tag{3}$$

where:

$$\begin{cases} A_2 = 2 \cdot OA \cdot AB \cdot \cos\varphi_1 \\ B_2 = 2 \cdot OA \cdot AB \cdot \sin\varphi_1 - 2 \cdot AB \cdot OC \\ C_2 = BC^2 - OA^2 - AB^2 - OC^2 + 2 \cdot OA \cdot OC \cdot \sin\varphi_1 \end{cases} \tag{4}$$

$$\begin{cases} \cos\varphi_3 = -\dfrac{1}{BC} \cdot (OA \cdot \cos\varphi_1 + AB \cdot \cos\varphi_2) \\ \sin\varphi_3 = -\dfrac{1}{BC} \cdot (OA \cdot \sin\varphi_1 + AB \cdot \sin\varphi_2 - OC) \end{cases} \tag{5}$$

$$\sin\varphi_4 = -\frac{1}{DE} \cdot (CD \cdot \sin\varphi_{3'} + CM) \tag{6}$$

$$s_5 = CD \cdot \cos\varphi_{3'} + DE \cdot \cos\varphi_4 \tag{7}$$

The relations above have been obtained by solving the following systems of equations settled by projecting the vector circuits corresponding to the two mentioned independent contours on the *x* and *y* axes [3]:

$$\begin{cases} OA \cdot \cos\varphi_1 + AB \cdot \cos\varphi_2 + BC \cdot \cos\varphi_3 = 0 \\ OA \cdot \sin\varphi_1 + AB \cdot \sin\varphi_2 + BC \cdot \sin\varphi_3 - OC = 0 \end{cases} \tag{8}$$

$$\begin{cases} CD \cdot \cos\varphi_{3'} + DE \cdot \cos\varphi_4 - s_5 = 0 \\ CD \cdot \sin\varphi_{3'} + DE \cdot \sin\varphi_4 + MC = 0 \end{cases} \tag{9}$$

where: $\varphi_{3'} = \varphi_3 + \dfrac{4\pi}{3}$.

The angular and linear speeds and accelerations distributions have been determined by deriving the variation functions of the corresponding position parameters.

A computer program that simulates the mechanism functioning has been developed. The results concerning the variation of the necessary motor moment obtained with this computer program are presented in tables 1 and 2.

For the two tables the values of the motor moment have been calculated by considering that *OC* varies between 0.48m and 0.64m.

The values of the motor moment in table 1 correspond to the case (denoted as case 1) when: $k_{f_{ru}^{dr}} = 1500 \dfrac{\mathrm{N \cdot s}}{\mathrm{m}}$; $k_{f_{ru}^{st}} = 150 \dfrac{\mathrm{N \cdot s}}{\mathrm{m}}$ and $M_{ru} = 120\mathrm{Nm}$.

The values of the motor moment in table 2 correspond to the case (denoted as case 2) when: $k_{f_{ru}^{dr}} = 3000 \frac{\mathrm{N \cdot s}}{\mathrm{m}}$; $k_{f_{ru}^{st}} = 300 \frac{\mathrm{N \cdot s}}{\mathrm{m}}$ and $M_{ru} = 180 \mathrm{Nm}$.

Table 1. The values of the motor moment for the case 1

OC [m]	0.48	0.52	0.56	0.6	0.64
M_m [Nm]	30.1	30.3	31.3	33.5	38.1

Table 2. The values of the motor moment for the case 2

OC [m]	0.48	0.52	0.56	0.6	0.64
M_m [Nm]	52.3	52.9	54.9	59	67.5

Conclusions

In this paper the variation of the motor moment in the case of a plane mechanism is analyzed. The motor moment is calculated using the reduced moment corresponding to the technological forces and moments that work on the component links of the mechanism. A computer program that simulates the mechanism functioning has been developed. This computer program permits to analyze the variation of the motor moment when there are variations of the technological loads and of the dimensions corresponding to some component links.

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Cercetări privind variația momentului motor în cazul unui mecanism plan

Rezumat

In articol se analizează variația momentului motor în cazul unui mecanism plan. Momentul motor este calculat folosind momentul redus corespunzător forțelor şi momentelor tehnologice care acționează asupra elementelor mecanismului. Forțele tehnologice variază proporțional cu viteza elementelor asupra cărora lucrează. Un program de calculator care simulează funcționarea mecanismului a fost dezvoltat.