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AN APPROACH OF OSCILLATING CYLINDER MECHANISM SYNTHESIS

BY

FLORENTIN BUIUM* **and CEZAR DUCA**

“Gheorghe Asachi” Technical University of Iaşi

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Abstract. The paper proposes a practical and easy for use method of the oscillating cylinder mechanism synthesis, named by authors' elementary synthesis. First, the problem of oscillating cylinder elementary synthesis is formulated and then the steps to apply this procedure are presented. The paper contains the main ideas, original contributions and conclusions of the authors' research.

Key words: oscillating cylinder, mechanism, elementary synthesis.

1. Introduction

In technical general meaning, dimensional synthesis of mechanisms expresses the operation of constructive parameters determining. The dimensional synthesis problem is large and varied, respecting the functional role of each component mechanism into machines. The functional conditions can be kinematical (positions, velocities and accelerations) or dynamical (force transmission). Mathematical model consists of equation or non equation systems. Generally, these systems are non linear ones and are solvable by numerical methods. Through the multitude of dimensional synthesis problems it can select several of them, being of great practical importance and frequently

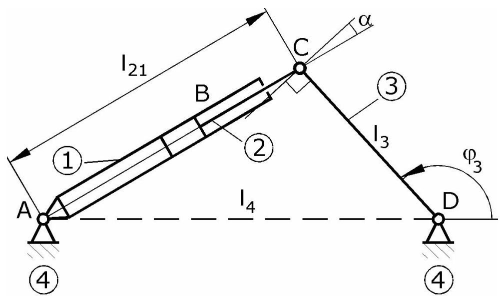
*Corresponding author; *e-mail*: fbuium@yahoo.com

used in linkage designing. We agreed these problems to be named by elementary synthesis. The other synthesis problems intervene rarely in practice and are more difficult to solve by numerical methods.

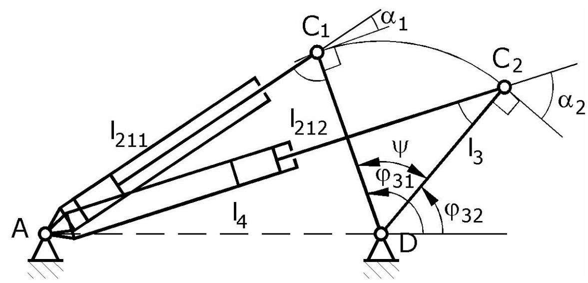
Elementary synthesis consists in authors' conception, of four problems: rotability, synthesis to assure the force transmission quality, synthesis depending on the extreme positions of driven link and synthesis depending on the productivity coefficient. Besides these, the four synthesis problems intervene together in the synthesis process of a mechanism. As is known, synthesis providing the force transmission quality, solves the driven link rotability too. The three remain problems form the combined elementary synthesis. Its mathematical model is obtained by bringing together the specific equations and non equations of component problems (Artobolevskii, 1970; Duca, 1983; Duca *et al.*, 2003a; Duca *et al.*, 2003b; Duca, 2005; Dudiță *et al.*, 1989; Erdman *et al.*, 2001; Frolov, 1987; Jensen, 1991).

2. Elementary Synthesis of Oscillating Cylinder Mechanism

For this mechanism, driven by a sliding joint, the rotability and productivity coefficient problem do not intervene. Therefore, synthesis depending on pressure angle and that depending on extreme positions of driven link concern only. In addition these two problems are tight related each other.



a



b

Fig. 1 – The oscillating cylinder mechanism
a – characteristic parameters; *b* – extreme positions of driven links.

A problem of great importance refers to positioning of the driven link 3 oscillating angle (ψ) (Fig. 1 *a*), in order to obtain as less as possible pressure angles. Thus it express the pressure angle as function of φ_3 angle, through the angle $\hat{C} = \angle ACD$ and the length l_{21} (Fig. 1 *b*).

$$\alpha = \left|\hat{C} - \frac{\pi}{2}\right| \tag{1}$$

$$\hat{C} = \arccos\frac{l_{21}^2 + l_3^2 - l_4^2}{2l_{21}l_3}, \quad l_{21} = \sqrt{l_3^2 + l_4^2 + 2l_3l_4\cos\varphi_3}\ .$$

Functions $\alpha(\varphi_3)$ and $\hat{C}(\varphi_3)$ are represented in Fig. 2 *a* for $l_3 < l_4$ and in Fig. 2 *b*, for $l_3 > l_4$. The useful for φ_3 interval, having the length equals the angular lift ψ, is defined by the angles φ_{31} and φ_{32}, which determine the angular positions of link 3.

The maximum value of the pressure angle on this interval is one of the two values corresponding to the extreme positions $\alpha_{\max} = \max(\alpha_1, \alpha_2)$. Obviously, to optimize (minimize) $\alpha_{\max}$, the interval $[\varphi_{31}, \varphi_{32}]$ has to be adopted so that $\alpha_1 = \alpha_2 = \alpha_{\max}$.

In the case $l_3 < l_4$ (Fig. 2 *a*) $\hat{C}_1 > \frac{\pi}{2}$ and $\hat{C}_2 < \frac{\pi}{2}$ that, from $\alpha_1 = \alpha_2$ it result $\hat{C}_1 + \hat{C}_2 = \pi$. Consequently, the two extreme positions of mechanism show as in Fig. 3, the lines AC_1 and AC_2 being collinear. It results $\alpha_{\max} = \alpha_1 = \alpha_2 = \frac{\psi}{2}$, which shows that maximum pressure angle depends on the maximum angular displacement ψ only, and do not depends on the l_3 and l_4. From condition $\alpha_{\max} \le \alpha_a$ it obtains that $\frac{\pi}{2} \le \alpha_a$, showing that input parameters α_a and ψ have to be correlated.

The synthesis mathematical model is composed by three equations, deducted using Fig. 3, having unknowns l_3, l_4, AC_1, AC_2 and h_p (the piston lift).

$$\left(\frac{AC_1 + AC_2}{2}\right)^2 + l_3^2\cos^2\frac{\psi}{2} = l_4^2\ . \tag{2}$$

$$\sin\frac{\psi}{2} = \frac{h_p}{2l_3}\ . \tag{3}$$

$$h_p = AC_2 - AC_1\ . \tag{4}$$

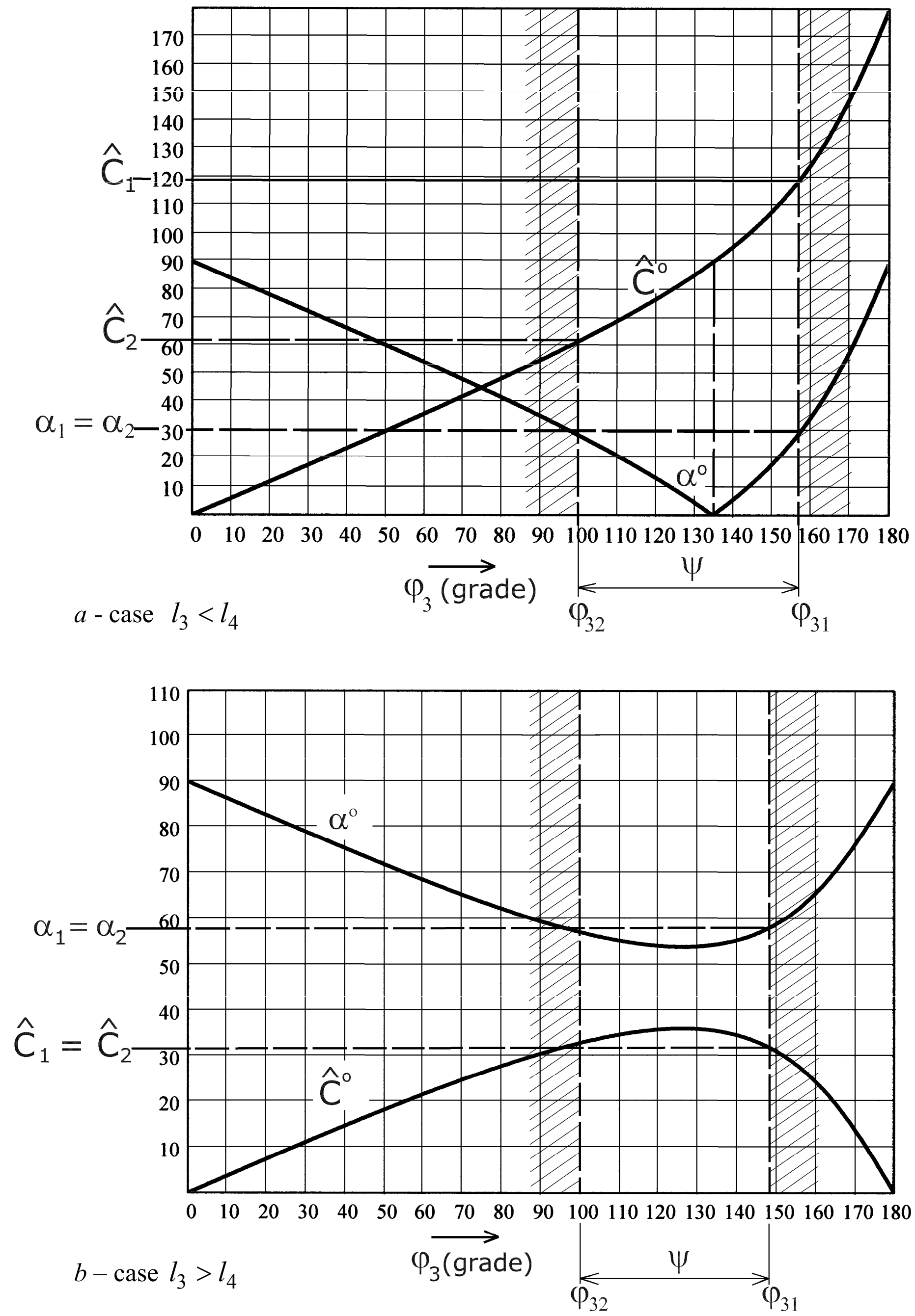


Fig. 3 – Functions $\alpha(\varphi_3)$ and $\hat{C}(\varphi_3)$.

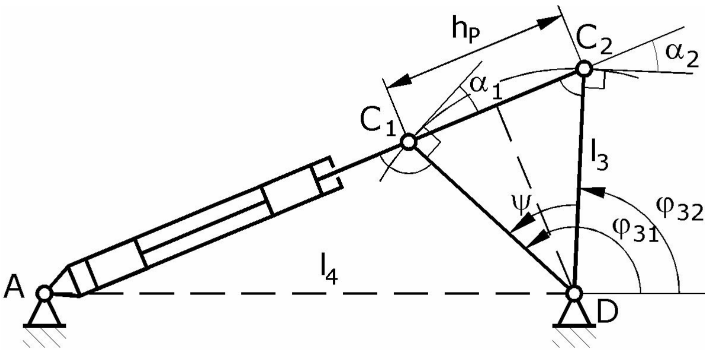
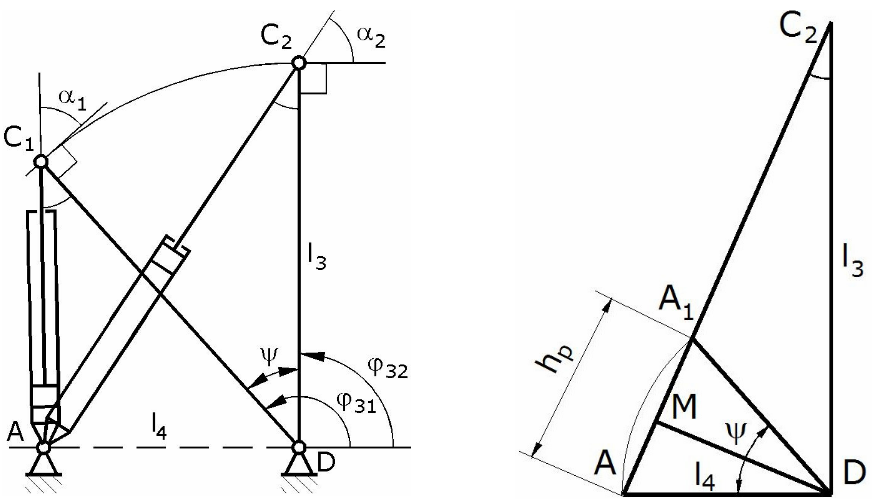


Fig. 3 – Geometric scheme of synthesis parameters calculus.

To solve these equations, the length l_3 is adopting according to mechanism destination. After piston lift h_p calculus it can choose the hydraulic driver and implicit $AC_1 = l_{21\min}$ and $AC_2 = l_{21\max}$, which are the technical parameters of this driver. Finally, l_4 determines from relation (2).

In the case $l_3 > l_4$ (Fig. 2*b*), $\hat{C} \in \left[0, \frac{\pi}{2}\right]$, so that if $\alpha_1 = \alpha_2$, it results $\hat{C}_1 = \hat{C}_2$. The two extreme positions of mechanism show like in Fig. 4 *a*.



a *b*

Fig. 4 – The $l_3 > l_4$ case:
a – extreme positions of mechanism; *b* – calculus scheme.

In order to find easily the synthesis conditions, it rotates the AC_1D triangle round about point D, respecting angle the ψ, until point C_1 touches C_2 (Fig. 4 *b*). The point A moves to A_1 on the line C_2A, because $\hat{C}_1 = \hat{C}_2$. From the AC_2D triangle (Fig. 4 *b*), it results:

$$\sin \hat{C}_2 = \frac{l_4 \cos \frac{\psi}{2}}{l_3}; \quad \hat{C}_2 = \frac{\pi}{2} - \alpha_2 ;.$$

$$\alpha_{\max} = \alpha_1 = \alpha_2 = \arccos\left(\frac{l_4}{l_3} \cos \frac{\psi}{2} \right) \le \alpha_a . \tag{5}$$

The synthesis conditions, deduced from Fig. 4*b*, are:

$$\left(\frac{C_2A_1 + C_2A}{2} \right)^2 + l_4^2 \cos^2 \frac{\psi}{2} = l_3^2 . \tag{6}$$

$$\sin \frac{\psi}{2} = \frac{h_p}{2l_4} . \tag{7}$$

$$h_p = C_2A - C_2A_1 . \tag{8}$$

The unknowns of this problem are l_3, l_4, C_2A, C_2A_1 and h_p. The mathematical model is similar to the previous case, if inverses l_3 with l_4. To obtain a solution, it satisfactory adopts l_4, it calculates h_p and it choose the hydraulic driver, determining in this way $C_2A_1 = l_{21\min}$ and $C_2A = l_{21\max}$. Then, it calculates the length l_3, using the equation (6). Finally, it verifies the relation (5), which shows that as less the report $\frac{l_4}{l_3}$, as greater $\alpha_{\max}$.

In the Fig. 5, it shows the function $\alpha_{\max}(\psi)$, for the different values of the $\frac{l_4}{l_3}$ report. It also notices that in this case ($l_3 > l_4$), the maximum pressure angle ($\alpha_{\max}$) gives greater values than in previous case ($l_3 < l_4$), that is more favourable of this point of view.

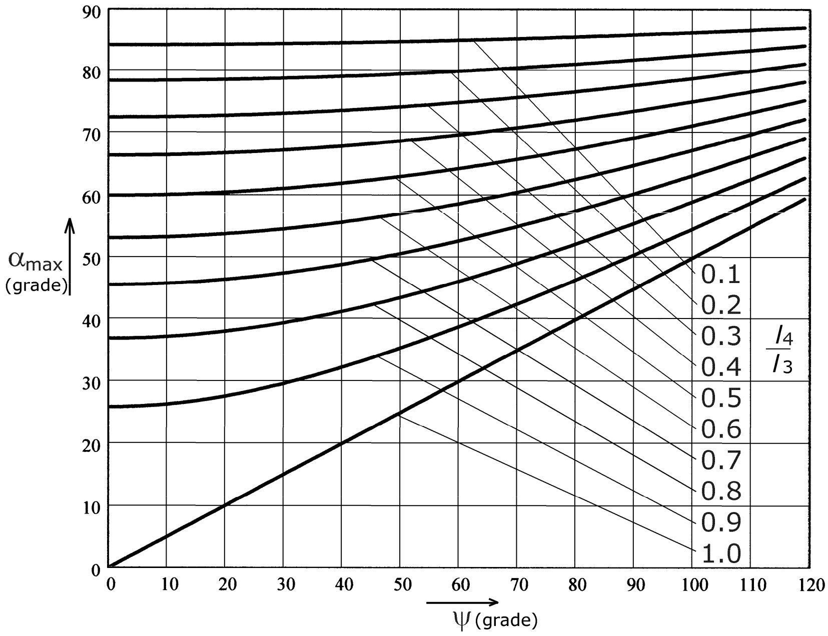


Fig. 5 – The diagrams $\alpha_{\max}(\psi)$.

The limit case $l_3 = l_4$, to which can be applied every of the two mathematical models, leads to the $l_{21\min} = 0$, that is constructively unfavourable.

4. Conclusions

1. Paper approaches a synthesis problem, less treated in technical literature, respectively the oscillating cylinder mechanism elementary synthesis. The pressure angle and extreme position of driven link constitutes the principal synthesis criteria for this mechanism, therefore problem consists of minimize this angle, respecting the extreme positions and angular lift. Also, a very important data is position of angular lift (ψ);

2. The performed geometrical schemes and mathematical model shows that in this problem two distinct cases appear ($l_3 > l_4$ and $l_3 < l_4$);

3. The maximum pressure angle of the oscillating cylinder mechanism depends on the angular lift (ψ) only and do not depends on the lengths l_3, l_4;

4. According to diagrams $\alpha_{\max}(\psi)$, maximum pressure angle varies inverse proportional with l_4 / l_3 report and the most favourable situation in this aspect is the case $l_3 < l_4$.

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O METODĂ DE SINTEZĂ A MECANISMULUI CU CILINDRU OSCILANT

(Rezumat)

Lucrarea prezintă o metodă pentru sinteza elementară a mecanismului cu cilindru oscilant. În cazul de față, prezintă interes sinteza funcție de unghiul de presiune şi sinteza funcție de pozițiile extreme ale elementului condus. După ce, în prealabil s-a calculat unghiul de presiune, se disting două situații în problema de sinteză combinată a acestui mecanism, în funcție de mărimea raportului l_4/l_3, (subunitar sau supraunitar). În funcție de mărimea acestui raport s-a elaborat modelul matematic al operației de sinteză precum şi metodologia aferentă de sinteză pentru fiecare caz în parte.