THE SYNTHESIS COMPLEX MECHANISM OF GUIDING ROOF SUPPORTS FOR THE COAL MINING

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ABSTRACT *The paper brings forward the results of the study with respect to the synthesis of complex mechanism of guiding roof supports for the coal mining. The mechanism of guiding roof supports for the coal must fulfil the following functions: leading the beam shield on a course roughly rectilinear, parallel to the coal face, to gauge how much lower the front-operated space, packaging as well as the support that it can be transported in assembled condition, not to obstruct the free spaces of the roof support it belongs to. The geometric parameters of the complex mechanism shall be determined using the method of vector contours with vectors expressed in their complex form.*

KEY WORDS: mechanism, coal, support, parameter, vector

1. METHOD PRESENTATION

The paper brings forward the approximate synthesis of the equidistancing complex mechanism in which the values of geometrical parameters which define it are imposed, in order to result into mechanisms which may be used as equidistancing mechanisms comprised by the mechanised roof supports.

The complex equidistancing mechanism derives from a 4R quadrilateral articulated mechanism obtained through the amplification with a structural group (3R dyad), Figure 1. After the amplification using the mentioned dyad the obtained mechanism maintains the mobility degree of the basic mechanism (four bar linkage) but it increases its number of elements (from four to six) and the number of kinematic joints (from four to seven) increasing therefore the use space and the range of possible moves with the new mechanism. Figure 1 presents the modality in which the complex mechanism is obtained through the amplification of the 4R quadrilateral mechanism with a 3R dyad. The later one was connected to the rod in point M to the balancing lever A_0A_1 in point F. The quadrilateral mechanism is a complex double balancing mechanism.

It has been taken into consideration the case where the closed contour by adding the 3R dyad is a parallelogram contour with equal sides, to be simplified in the algorithm, without reducing the moving performances of point C.

From the analysis of Figure 2 it may be observed that the elements A_0F and FC are the main central elements of the mechanism, the dimensions and positions of which decisively influence the weight and the form of the complex mechanism. From the analysis of Figure 2 it may be observed that the elements A_0F and FC are the main central elements of the mechanism, the dimensions and positions of which decisively influence the weight and the form of the complex mechanism. From the analysis of Figure 2 it may be observed that the elements A_0F and FC are the main central elements of the mechanism, the dimensions and positions of which decisively influence the weight and the form of the complex mechanism.

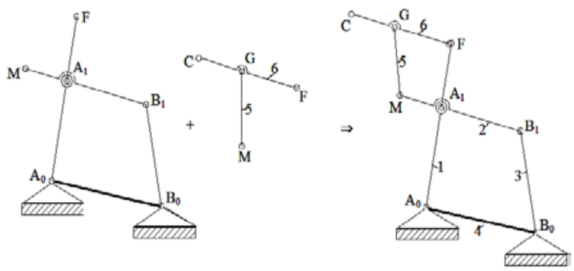

Fig. 1. Attachment the 3R dyad to the 4R four bar linkage

Starting from this observation, in order to appoint the data for the created synthesis algorithm, the following general data were taken into consideration:

The directions of the axes of the reference system plan xOy are specified;

The existence domain D and the form of the trajectory of the articulation beam-shield are specified by imposing the system of points C_j, $j=\overline{1,5}$ through which it passes;

One of the five C_j points is chosen, for instance point C_1 (thinking of the packaged form of the mechanism), though which line (d_1) is drawn with a direction β_7 considering the positive sense of the Ox axis with a value smaller than 180^o;

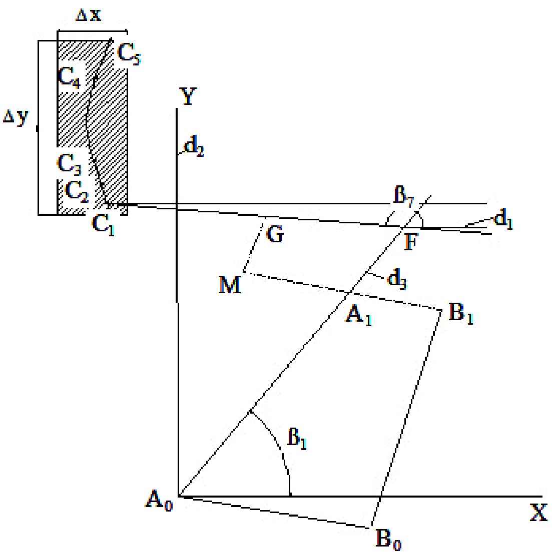

Fig. 2. The complex equidistancing mechanism, calculation diagram

The direction (d2)‖Oy is arbitrarily drawn on which, through several trials, the fixed articulation A_0 is chosen, in which the origin O of the reference system $O \equiv A_0$ shall also be considered; from this point the line (d_3), with an angle of slope β_1 the value of which situates it in the first half of quadrant one, is drawn;

The intersection of lines (d_1) and (d_3) is marked F obtaining therefore, according to Figure 2, the lines $A_0F=(z_1+z_5)$ and $FC=(z_6+z_7)$;

It is therefore chosen, by repeating the above mentioned scenarios where the lengths of A_0F and FC_1 are the most corresponding ones;

The kinematic chain $A_0B_0B_1MG$ is also added to the construction, obtaining finally the structure presented in Figure 3 for which the following set of initial data is specified in order to write the synthesis algorithm;

The domain D for framing the trajectory of the point of rod C defined through a set of initial data in order to write the synthesis algorithm:

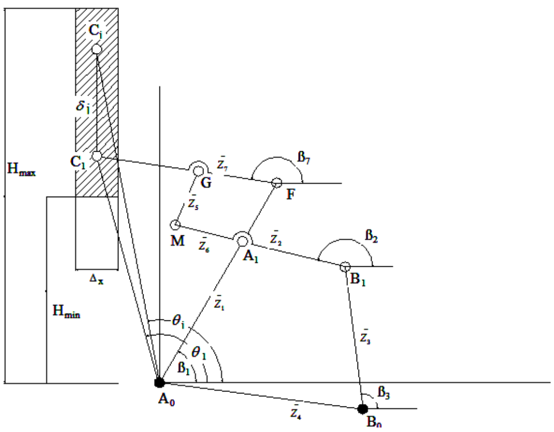

Fig. 3. The layout of the synthesis problem

The length of line A_0F and the angle β_1 of orientation towards the positive direction of the axis Ox in initial position;

The position of the fixed joint $A_0(0,0)$;

The closed rhombic contour A_1MGF.

Considering the notes in Figure 3 and the above mentioned data, the following relations may be written:

$$z_6 = z_5 \tag{1}$$

$$z_7 = FC_1 - z_6 \tag{2}$$

$$x_F=(z_1+z_5)\cos\beta_1 \tag{3}$$

$$y_F=(z_1+z_5)\sin\beta_1 \tag{4}$$

The known terms are:

$A_0F=z_1+z_5; C_j(x_j,y_j), j=\overline{1,5}; \beta_1; \beta_2=\beta_7; \beta_5=\beta_1;$ $A_0(x_{A0},y_{A0})$, namely 16 data.

The other geometrical parameters which define the complex mechanism are unknown: z_2; z_3; z_5; β_3; φ_j; ψ_j; $\gamma_j=\varepsilon_j$, $j=\overline{2,5}$, namely 16 unknowns.

The definitive geometrical elements of the mechanism are expressed as follows, Figure 3:

- The sides of the mechanism,

$$\bar{z}_k = z_k \cdot e^{i\varphi_k};\ k=\overline{1,7} \tag{5}$$

- The operators of the revolutions of the elements,

$$\lambda_j = e^{i\varphi_j}, \nu_j = e^{i\gamma_j},\ \mu_j = e^{i\psi_j}, \chi_j = \nu_j;\ j=\overline{2,7} \tag{6}$$

- The movement of the rod point C_1 in positions C_j, where $j=\overline{2,5}$

$$\bar{\delta}_j = \bar{r}_j - \bar{r}_1,\ j=\overline{2,5} \tag{7}$$

The vector radiuses of points C_j, $j=\overline{1,5}$ close each two vectorial contours, the first in initial position and the second one in position j.

$$\bar{r}_1 = (\bar{z}_1 + \bar{z}_5) + (\bar{z}_6 + \bar{z}_7) = \bar{z}_3 + \bar{z}_4 + (\bar{z}_2 + \bar{z}_6) + \bar{z}_5 + \bar{z}_7 \tag{8}$$

$$\bar{r}_j = (\bar{z}_1 + \bar{z}_5)\lambda_j + (\bar{z}_6 + \bar{z}_7)\chi_j = \bar{z}_4 + \bar{z}_3 \cdot \mu_j + (\bar{z}_2 + \bar{z}_6) \cdot \nu_j + \bar{z}_5 \cdot \lambda_j + \bar{z}_7 \cdot \chi_j,\ j=\overline{2,5} \tag{9}$$

Considering relations (8) and (9), relations (7) receive the following form:

$$(\bar{z}_1 + \bar{z}_5)(\lambda_j - 1) + (\bar{z}_6 + \bar{z}_7)(\chi_j - 1) = \bar{\delta}_j \tag{10}$$

$$\overline{z_3}(\mu_j - 1) + (\overline{z_2} + \overline{z_6})(\nu_j - 1) + \\ + \overline{z_5} \cdot (\lambda_j - 1) + \overline{z_7}(\chi_j - 1) = \delta_j \tag{11}$$

Separating the terms of the real and imaginary part, relation (10) receives the following form:

$$\begin{cases} (\overline{z_1} + \overline{z_5}) \cdot [\cos(\phi_j + \beta_1) - \cos\beta_1] + \\ + (\overline{z_6} + \overline{z_7}) \cdot [\cos(\gamma_j + \beta_2) - \cos\beta_2] = \\ = r_j \cos\theta_j - r_1 \cos\theta_1 \\ (\overline{z_1} + \overline{z_5}) \cdot [\sin(\phi_j + \beta_1) - \sin\beta_1] + \\ + (\overline{z_6} + \overline{z_7}) \cdot [\sin(\gamma_j + \beta_2) - \sin\beta_2] = \\ = r_j \sin\theta_j - r_1 \sin\theta_1 \end{cases} \tag{12}$$

$$\begin{cases} (\overline{z_1} + \overline{z_5}) \cdot [\cos(\phi_j + \beta_1) - \cos\beta_1] + \\ + (\overline{z_6} + \overline{z_7}) \cdot [\cos(\gamma_j + \beta_2) - \cos\beta_2] = \\ = r_j \cos\theta_j - r_1 \cos\theta_1 \\ (\overline{z_1} + \overline{z_5}) \cdot [\sin(\phi_j + \beta_1) - \sin\beta_1] + \\ + (\overline{z_6} + \overline{z_7}) \cdot [\sin(\gamma_j + \beta_2) - \sin\beta_2] = \\ = r_j \sin\theta_j - r_1 \sin\theta_1 \end{cases} \tag{13}$$

While relation (11) becomes:

$$z_3[\cos(\psi_1 + \beta_3) - \cos\beta_3] + (z_2 + z_6) \cdot \\ [\cos(\gamma_1 + \beta_2) - \cos\beta_2] + z_5 \begin{bmatrix} \cos(\phi_j + \beta_1) \\ -\cos\beta_1 \end{bmatrix} + \\ + z_7[\cos(\gamma_j + \beta_2) - \cos\beta_2] = r_j \cos\theta_j - r_1 \cos\theta_1 \tag{14}$$

$$z_3[\sin(\psi_1 + \beta_3) - \sin\beta_3] + (z_2 + z_6) \cdot \\ [\sin(\gamma_1 + \beta_2) - \sin\beta_2] + z_5 \begin{bmatrix} \sin(\phi_j + \beta_1) \\ -\sin\beta_1 \end{bmatrix} + \\ + z_7[\sin(\gamma_j + \beta_2) - \sin\beta_2] = r_j \sin\theta_j - r_1 \sin\theta_1$$

Relations (10) and (11) represent each a system of four vectorial equations containing 8 scalar unknowns, i.e. ϕ_j and γ_j in system (13) and ψ_j, z_2, z_3, β_2, β_3 in system (14).

Some of the geometric parameters of the mechanism may be determined with the additional relations:

$\overline{FC_1} \equiv \overline{z_6} + \overline{z_7}$, in its initial position (15)

$$\overline{FC_1} = \sqrt{A^2 + B^2} \tag{16}$$

$$\beta_7 = \text{arctg}\frac{B}{A} = \beta_2 \tag{17}$$

Where: $A = (z_1 + z_5)\cos\beta_1 - x_{C_1}$ (18)

$B = (z_1 + z_5)\sin\beta_1 - y_{C_1}$ (19)

The position vectors $\overline{r_j}$ of points C_j, $j=\overline{1,5}$ on the trajectory imposed to the beam-shield joint are defined using the following relations:

$$|r_j| = \sqrt{x_{C_j}^2 + y_{C_j}^2} \tag{19}$$

$$\theta_j = \text{arctg}\left|\frac{y_{C_j}}{x_{C_j}}\right| \tag{17}$$

2. APPLICATION

The following input data in mm were taken into consideration for exemplification: $ß_1=22.89^o$; $ß_2=171.84^o$; $x_{A0}=0$; $y_{A0}=0$; $x_{C1}=-630.011$; $y_{C1}=1189.594$; $x_{C2}=653.108$ $y_{C2}=1533.051$; $x_{C3}=-676.48$ $y_{C3}=1841.58$; $x_{C4}=-701.803$; $y_{C4}=2125.657$; $x_{C5}=-729.043$ $y_{C5}=2391.492$

The following data are determined while running the synthesis algorithm: $A_0F=2110$ mm $FC_1=1346.12$ mm $ß_2= ß_7=171.84^o$.

The mechanism presented in Figure 4 was obtained when the presented algorithm was run, mechanism the form of which is acceptable for a guiding mechanism of a mechanised roof support.

$$r_j = \begin{bmatrix} 1346{,}123 \\ 1666{,}372 \\ 1961{,}904 \\ 2238{,}514 \\ 2500{,}148 \end{bmatrix} \quad \theta_j = \begin{bmatrix} 117{,}905 \\ 113{,}074 \\ 110{,}170 \\ 108{,}271 \\ 106{,}953 \end{bmatrix}; \quad j=\overline{1,5}$$

Having solved the two nonlinear systems with the use of the MATHCAD software the following unknowns have resulted:

$\varphi_2=4^o$; $\varphi_3=8^o$; $\varphi_4=12^o$ $\varphi_5=16^o$; $\gamma_2=-4{,}7^o$; $\gamma_3=-8{,}8^o$; $\gamma_4=-12{,}53^o$; $\gamma_5=-16{,}067^o$

$Z_3=1414{,}24$; $z_2=413{,}009$; $\psi_2=3{,}43^o$; $\psi_3=7{,}12^o$; $\psi_4=11{,}004^o$; $\psi_5=15{,}03^o$; $\beta_3=36{,}58^o$

After having determined all the geometric elements the positional kinematic analysis of the synthesised mechanism is then carried out, obtaining the real trajectory of the beam-shield joint C verifying that it is comprised within the domain D and meeting the deviation Δx.

3. CONCLUSIONS

The method brought forward in the paper represents for the designers of mechanised roof supports the means for the synthesis of complex equidistancing mechanisms.

The obtained mechanism amplifies the possibilities of covering large face wall heights not letting the lengths of the interlaid kinematic chain between the sole and the beam to reach unacceptable values.

The use effects of complex equidistancing mechanisms are great:

- A reduced weight mechanism is obtained on the direction of the front-mined space;
- The mechanism has a good packaging;
- The stability of the mechanism on the direction of the front-mined space is very good.

The attached dyad considering the above mentioned conditions does not complicate the algorithm which corresponds to the synthesis of the 4R quadrilateral basic mechanism.

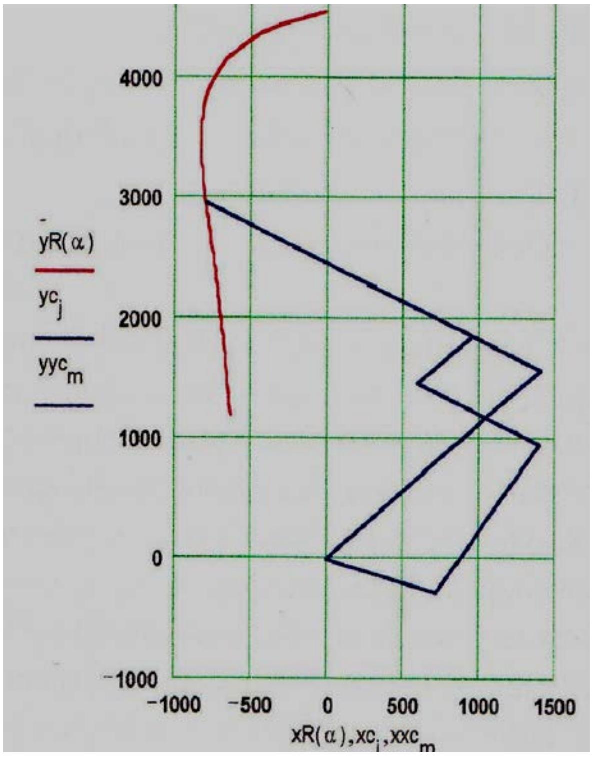

Fig. 4. The complex equidistancing synthesised mechanism

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