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Modification of Mechanism Kinetostatic Regarding Fitting Tolerance

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ABSTRACT

The effect of fitting tolerance over reactions from cinematic pairs of in-plane mechanisms with additional constrains is illustrate for jointed parallelogram mechanism with additional constrain. It was analyzed the stress from mechanism elements produced by a permissible variation less then the recommended permissible variation The results show that fitting tolerances, even are in permissible variations domain, influence the reactions from cinematic pairs and give out stress in elements of mechanism with additional constrain, leading to overstraining of them. In this way, is necessary more attention in choosing of accuracy class to build-up the mechanisms, not only by the familiar criterions, but also is needed to taking into consideration the supplementary stress that is given by the deviations.

***Keywords**: fitting tolerance, additional constrains*

1. Analyze hypothesis.

The effect of fitting tolerance over reactions from cinematic pairs of in-plane mechanisms with additional constrains is illustrate for jointed parallelogram mechanism with additional constrain from fig. 1.

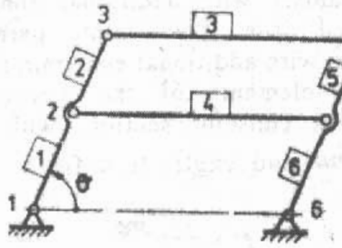


Fig. 1

In hypothesis that an element (i.e. element 4) has a length variation noted u, the goal is to establish the reactions from cinematic pairs, reactions that are produced only by this deviation.

If is admitted the deviation of element 4 in node 2, this will have in x direction two displacements noted Δ_i and Δ_j (fig. 2).

Displacement Δ_i is for point 2 from the crank, and Δ_j is the displacement of the same point from the rod.

Length variation u could be positive or negative, depends by their direction on x axis.

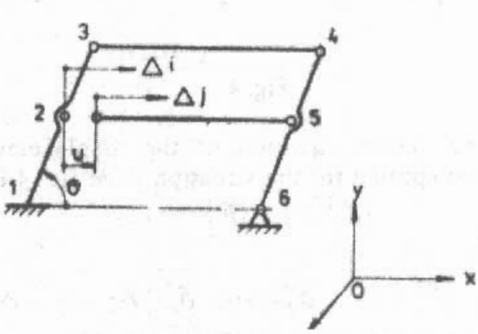


Fig. 2

In fig. 2, the joint 1 was transformed into constraining, thus accomplished separation of elastic deformations of the elements from displacements of solid. For this situation (fig. 2) is establish the stiffness matrix of the structure, $[K]$, corresponding to vector of nodes displacements $\{\Delta\}$. The vector of nodes displacements $\{\Delta\}$ has an additional component towards regular situation from fig. 3, because node 2 has two displacements Δ_i and Δ_j.

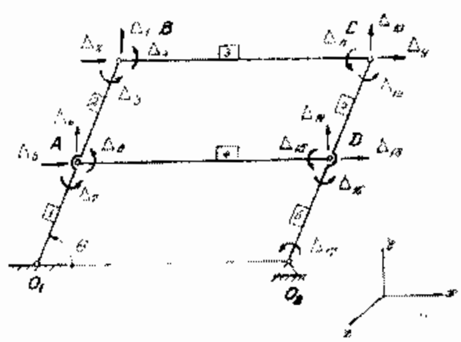


Fig. 3

2. The displacements method like solution for the proposed problem

Loading the system from fig. 2 with two equals unit forces, but opposed, on direction of degree of freedom i and j (fig. 4), from matrix equation of the displacements method applied for this loading situation it could be determined the displacement of all the nodes.

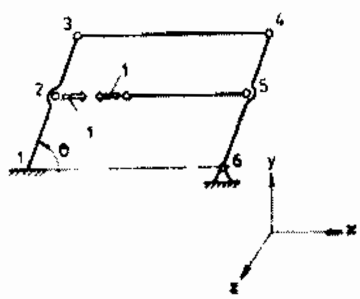


Fig. 4

The matrix equation of the displacements method applied for the situation from fig. 4 is:

$$[K]\{\delta\}=\{F\} \qquad (1)$$

Where:

- $\{\delta\}=\{\delta_1 \quad \delta_2 \quad \cdots \quad \delta_i \quad \delta_j \quad \cdots \quad \delta_n\}^T$ is vector of nodes displacements,
- $[K]$ is stiffness matrix,
- $\{F\}=\{0 \quad \cdots \quad 0 \quad F_i \quad F_j \quad 0 \quad \cdots \quad 0\}^T$ is the vector of external stress from nodes, where $F_i=1$, $F_j=-1$.

From equation (1) result the displacements of the node 2, δ_i and δ_j, on the direction of the degree of freedom i and j, displacements that are produced by unit stress.

Considering that element 4 is getting up with error u if is noted Q the force that appears at fitting on direction of the degree of freedom, the displacements of the node 2 will be:

$$\Delta_i=Q\cdot\delta_i, \quad \Delta_j=Q\cdot\delta_j \qquad (2)$$

Where δ_i and δ_j result from equation (1).

Since fitting condition could be expressed like:

$$\Delta_i-\Delta_j=u \qquad (3)$$

And taking into account equations (2) could be computed the force Q that appear at fitting:

$$Q=\frac{u}{\delta_i-\delta_j} \qquad (4)$$

Now, with force Q and vector of nodes displacements $\{\delta\}$, produced by unit stress, is established the vector of the nodes displacements $\{\Delta\}$, that are produced by fitting of the element 4 with error u in node 2, (fig.2):

$$\{\Delta\}=Q\,\{\delta\} \qquad (5)$$

After determination of the vector of nodes displacements $\{\Delta\}$, to establish reactions from connections and maximum stress from elements of considered mechanism, it tracing regular stages from structures calculus using displacements method.

3. Numeric application for analysis of fitting tolerance influence over reactions from cinematic pairs

The analysis of the fitting tolerance influence over reactions calculus from cinematic pairs of the mechanism with additional constrains is exemplified for the joint parallelogram mechanism with additional constrain from fig.5.

The elements of the mechanism are beams with constant section, with diameter $d=20[mm]$ and lengths from fig. 5.

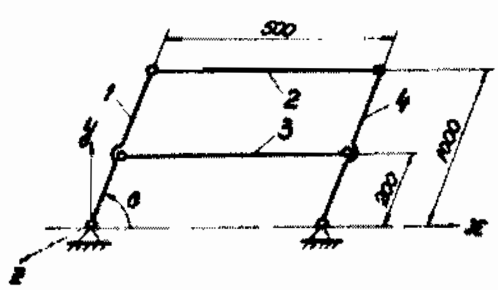
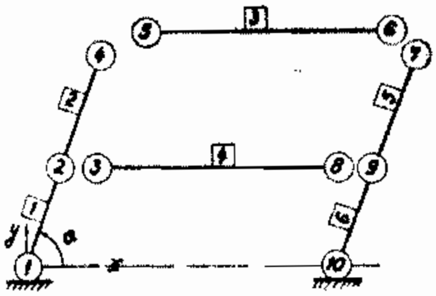


Fig.5

If is admitted for the passive element (3) an error $u=0{,}01[mm]$, establishing the forces that appear at fitting regarding equation (4), is needed the calculus of the nodes displacements resulted from unit forces (fig. 4). The calculus was accomplished using department software.



The numbering of nodes and considered beams at analyzed mechanism is show in fig. 6. The unit forces at nodes 2 and 3 are inlaid into software in this way:

$$F_2 = 1, \quad F_3 = -1$$

and are obtained nodes displacements. The values of the force that appear at fitting Q, computed from equation (4), for different positions of the mechanism are show in table 1

Based on the obtained results was computed the vector of nodes displacements $\{\Delta\}$, displacements that was produced by fitting of the passive element with error, and also was computed the vector of forces from elements nodes, with equation:

$$\{F\} = [k] \cdot \{\Delta\} \tag{6}$$

where:

- $\{F\} = \{F_1 \quad F_2 \quad \cdots \quad F_6\}$
- $[k]$, is stiffness matrix of the element in global coordinate system.

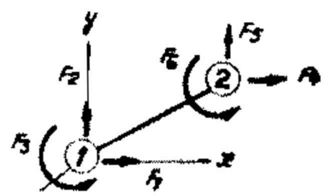
Table 1

$\delta_2 - \delta_3$ $[cm]$	$Q = \dfrac{u}{\delta_2 - \delta_3}$	θ $[grad]$
$0{,}397 \cdot 10^{-3}$	2,520	30
$0{,}118 \cdot 10^{-2}$	0,844	60
$0{,}158 \cdot 10^{-2}$	0,633	90
$0{,}118 \cdot 10^{-2}$	0,844	120
$0{,}397 \cdot 10^{-3}$	2,520	150

Thus was obtained the vectors of forces at nodes from elements 3 and 4, for different positions of the mechanism, and are presented in table 2.

Table 2

$$\{F\} = \begin{Bmatrix} F_1 \\ F_2 \\ \vdots \\ F_6 \end{Bmatrix}$$



BEAM	NODE		NODE 1			NODE 2			θ $[grad]$
	1	2	F_1 $[daN]$	F_2 $[daN]$	F_3 $[daN]$	F_4 $[daN]$	F_5 $[daN]$	F_6 $[daN]$	
3	5	6	-794	1,64	41,15	794	-1,64	41,15	30
			-792,7	0,55	13,85	792,7	-0,55	13,85	60
			-791,4	0	0	791,4	0	0	90
			-792,7	-0,55	-13,85	792,7	0,55	-13,85	120
			-794	-1,64	-41,15	794	1,64	-41,15	150
4	3	8	-131,9	0,27	6,80	131,9	-0,27	6,80	30
			-131,9	0,092	2,29	131,9	-0,092	2,29	60
			-131,9	0	0	131,9	0	0	90
			-131,9	-0,092	-0,29	131,9	0,092	-0,29	120
			-131,9	-0,27	-6,80	131,9	0,27	-6,80	150

For other elements of the mechanism, the forces at nodes have insignificant values. Analyzing results is considered that the error lead to appearance of some big forces.

Stress in element 3:

- from axial stress $\sigma = 252{,}9 \cdot 10^6 \, [Pa]$
- from bending stress $\sigma = 52{,}4 \cdot 10^6 \, [Pa]$

The variations values recommended by accuracy classes are in table 3.

Table 3

Accuracy class	Variation [mm]
5	0,027
6	0,04
7	0,063
8	0,097

Looking at errors (variations) values recommended by accuracy classes is obviously that in element 3 and other elements of the mechanism, the stress that appear from this variations have major values than the values computed for the error $u = 0,01[mm]$.

In conclusion, fitting tolerances even are in zone of allowable variations, influence reactions from cinematic pairs, and giving up stress in elements of the mechanisms with additional constrains, that leads to overstraining.
Thus, is necessary more attention in choosing of accuracy class to build-up the mechanisms, not only by the familiar criterions [4], but also is needed to taking into consideration the supplementary stress that is given by the deviations.

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Rezumat

Influenţa toleranţelor de montaj, asupra reacţiunilor din cuplele cinematice ale mecanismelor plane cu legături suplimentare , se exemplifică pentru mecanismul paralelogram articulat cu legătură suplimentară. Au fost analizate solicitările din elementele mecanismului cauzate de o abatere admisă mai mică decât abaterea recomandată de clasele de precizie. Rezultatele obţinute au arătat că toleranţele de montaj, chiar dacă sunt în domeniul toleranţelor admisibile, influenţează reacţiunile din cuplele cinematice şi produc în elementele mecanismelor cu legături suplimentare tensiuni ce conduc la suprasolicitarea lor. Se impune astfel, alegerea cu atenţie a claselor de precizie pentru execuţia mecanismelor, nu numai după criteriile cunoscute, ci ţinând cont şi de solicitarea suplimentară produsă de abateri, elementelor şi cuplelor cinematiceale mecanismelor.

Zusammenfassung

Die Wirkung, Toleranz über Reaktionen von filmischem Paar In Ebene Mechanismen mit zusätzlich zu passen, zwingt ist illustriert für jointed Parallelogramm Mechanismus mit zusätzlich zwingt. Es wurde von einer zulässigen Veränderung die Spannung von Mechanismenelementen, die weniger dann die empfohlene zulässige Veränderung hergestellt worden sind, die Die Ergebnisse das zeigen, Toleranzen zu passen, sogar sind in zulässiger Veränderungsdomäne analysiert, beeinflußt die Reaktionen von filmischen Paaren und zwingt aus Spannung in Elementen des Mechanismus mit zusätzlich gibt, führend zu Überanstrengen von ihnen. Auf dieser Weise ist notwendige mehr Aufmerksamkeit in Wählen von Genauigkeitklasse zu Aufbau die Mechanismen, nicht nur durch die vertrauten Kriterien, sondern auch ist notwendig ziehen zu in Betracht die zusätzliche Spannung, der von den Abweichungen gegeben wird.