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GENERAL MATRIX MODEL AT THE SECOND LEVEL OF AUTOMATIC SYNTHESIS PROCEDURE OF THE MECHANISMS

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ABSTRACT
At the automatic synthesis procedure of the mechanisms three levels are used to determine the desired solution of motion.
In this paper a formulation for general matrix at the second level of automatic synthesis procedure of the mechanisms is elaborated.
For the model of study the equivalent mechanism of the copier-blade mechanisms is adopted.
The adopted model of the equivalent multi linkage mechanism is used to perform kinematics analyses and the results for position, velocity and acceleration are graphically presented.
Key words: Lathe, copier-blade mechanism, desired behavior, motion transformation matrix, general matrix model, operational constraint vector, building blocks

1. INTRODUCTION
The turning process for manufacture of the electric motors' rotating shafts is realized through lathe, which presents a complex mechanism transmitting motion from the copier to the blade, Figure 1. The lathe contains the mechanism which rotational motion at input transforms into translation motion at output. It means that copier performs rotational motion and blade realizes translation motion.
Input and output data are not linear and not interchangeable.
Using the alternate decomposition by the motion transformation matrix (MTM) method the equivalent multi linkage mechanism is built [1, 2, 3]. Based in MTM matrix for copier-blade model [1,2] and analysed models in [3] the geeral matrix at the second level of automatic synthesis is formulated.
The adopted model of equivalent multi linkage mechanism contains three basic mechanisms and can be analyzed using analytical methods based in its vector loop [4].
The results for angular velocity (OM4, OM7, OM10) and acceleration (EPS4, EPS7, EPS10) for three vector loops are graphically presented, as a good to conclude on the adopted alternate mechanism behavior.
The simulation of the kinematics analysis – velocity and acceleration for the certain points and linkages of adopted mechanism is realized using MATLAB software.

2. LATHE MODEL PRESENTED AS COPIER-BLADE MECHANISM

In the Figure 1. is shown the lathe known as TRAUB SINGLE SPIDLE AUTOMATIC TYPE TK – VERTICAL SLIDE REAR. The machine contains the copier-blade mechanism required to manufacture a rotating shaft during a turning process.

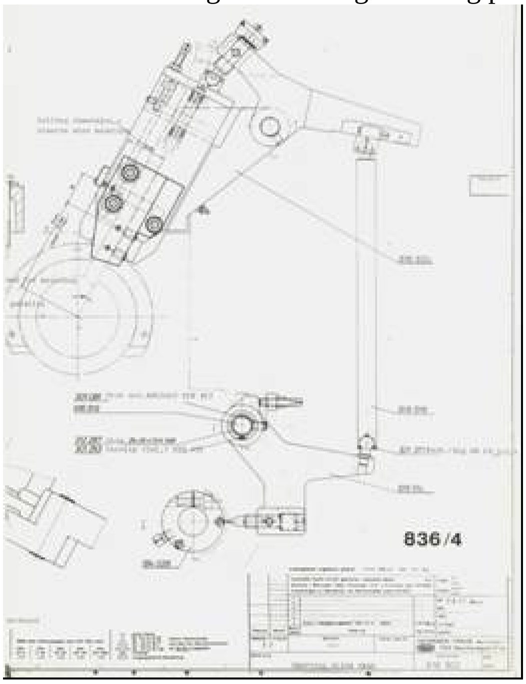

Figure 1. Lathe with copier-blade mechanism

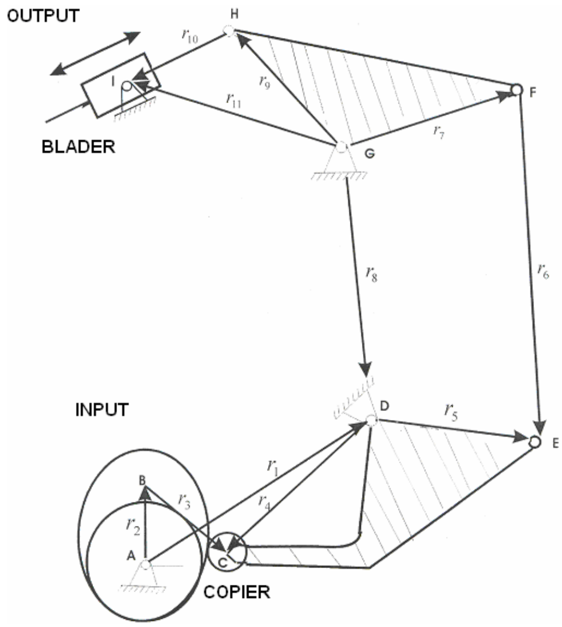

Figure 2. Vector loop for alternate multi linkage copier-blade mechanism

The task is solved through several steps [1,2,3]. First the desired motion transform matrices MTM^1 and MTM^2 are built knowing that the axis of input is perpendicular to the axis of the output, where the input is rotational motion (copier) and output is translation motion (blade). General form of the matrix at first level is given by

$$\underset{Output}{\begin{bmatrix} R \\ T \end{bmatrix}} \cdot \underset{Input^T}{\begin{bmatrix} R & T \end{bmatrix}^T} = \underset{\mathbf{MTM^1_{desired}}}{\begin{bmatrix} R\cdot R & R\cdot T \\ T\cdot R & T\cdot T \end{bmatrix}}, \qquad \underset{Output}{\begin{bmatrix} 0 \\ 1 \end{bmatrix}} \cdot \underset{Input^T}{\begin{bmatrix} 1 & 0 \end{bmatrix}^T} = \underset{\mathbf{MTM^1_{desired}}}{\begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix}} \tag{1}$$

If item '1' in equation (1) is replaced with '3' for perpendicularity, matrix for model has form as

$$MTM_{desired}{}^{1} = \begin{bmatrix} 0 & 0 \\ 3 & 0 \end{bmatrix} \tag{2}$$

Desired matrix MTM^2 at second level can be derived from specifications of the type of motion and orientation,

$$[Output\ Matrix] \otimes [Input\ Matrix]^T = [MTM^2{}_{desired}] \tag{3}$$

$$\underset{\mathbf{Output}}{\begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 1 \\ 0 \end{bmatrix}} \cdot \underset{\mathbf{Input^T}}{\begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}^T} = \underset{\mathbf{MTM^2_{desired}}}{\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}}, \text{ Input is rotation – Output translation} \tag{4}$$

The operational constraints are given in a vector form:

OCV$_{desired}$ = (Continuity, Linearity, Reversibility, Direction) (5)

$$OCV_{desired} = \left(1, \quad 0, \quad 0, \quad \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 1 & 0 \end{bmatrix}\right) \tag{6}$$

Output ***Input^T*** **Direction** **Output** **Input^T** **Direction**

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}^T = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \wedge \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} 0 & 1 & 0 \end{bmatrix}^T = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \tag{7}$$

In next steps it's matched desired MTM^1 with MTM^1 of the building blocks [1, 2, 3], finding that five building blocks matched with desired and one of them satisfied operational constraints. For generating additional solutions, the MTM^2 is decomposed into sub-functions [1, 2, 3] present at least one building block with its OCV.

Combination of the OCVs for the sub-functions is given:

$OCV_{sub-function2} \otimes OCV_{sub-function1} = OCV_{acquired}$

$OCV_{acquired}$ compares with $OCV_{desired}$. (8)

Finally, after combinations as an alternate mechanism for the lathe with copier-blade mechanism is chosen the six-linkage mechanism in combination with cam follower, Figure 2.

Based in the methodology elaborated for the adopted model, mathematically presented in (4) the general matrix model for different mechanism is formulated as:

$$\begin{bmatrix} R_{x0} \leftrightarrow R_{xi} & R_{y0} \leftrightarrow R_{xi} & R_{z0} \leftrightarrow R_{xi} & T_{x0} \leftrightarrow R_{xi} & T_{y0} \leftrightarrow R_{xi} & T_{z0} \leftrightarrow R_{xi} \\ R_{x0} \leftrightarrow R_{yi} & R_{y0} \leftrightarrow R_{yi} & R_{z0} \leftrightarrow R_{yi} & T_{x0} \leftrightarrow R_{yi} & T_{y0} \leftrightarrow R_{yi} & T_{z0} \leftrightarrow R_{yi} \\ R_{x0} \leftrightarrow R_{zi} & R_{y0} \leftrightarrow R_{zi} & R_{z0} \leftrightarrow R_{zi} & T_{x0} \leftrightarrow R_{zi} & T_{y0} \leftrightarrow R_{zi} & T_{z0} \leftrightarrow R_{zi} \\ R_{x0} \leftrightarrow T_{xi} & R_{y0} \leftrightarrow T_{xi} & R_{z0} \leftrightarrow T_{xi} & T_{x0} \leftrightarrow T_{xi} & T_{y0} \leftrightarrow T_{xi} & T_{z0} \leftrightarrow T_{xi} \\ R_{x0} \leftrightarrow T_{yi} & R_{y0} \leftrightarrow T_{yi} & R_{z0} \leftrightarrow T_{yi} & T_{x0} \leftrightarrow T_{yi} & T_{y0} \leftrightarrow T_{yi} & T_{z0} \leftrightarrow T_{yi} \\ R_{x0} \leftrightarrow T_{zi} & R_{y0} \leftrightarrow T_{zi} & R_{z0} \leftrightarrow T_{zi} & T_{x0} \leftrightarrow T_{zi} & T_{y0} \leftrightarrow T_{zi} & T_{z0} \leftrightarrow T_{zi} \end{bmatrix} \tag{9}$$

and

$$\begin{bmatrix} \begin{matrix} First \\ quadrant \\ ROTATION - ROTATION \end{matrix} & \begin{matrix} Second \\ quadrant \\ ROTATION - TRANSLATION \end{matrix} \\ \begin{matrix} Third \\ quadrant \\ ROTATION - TRANSLATION \end{matrix} & \begin{matrix} Fourth \\ quadrant \\ TRANSLATION - TRANSLATION \end{matrix} \end{bmatrix} \tag{10}$$

In Figure 2 is also shown vector loop for the equivalent multi linkage mechanism. With analytical methods based in a vector loop kinematics analysis were performed and some of results are graphically presented in Figure 3.

3. CONCLUSIONS

Based on analysis performed for both models, the model of lathe with copier-blade mechanism and the equivalent model of multi linkage mechanism it can be concluded that:

- The equivalent model of multi linkage mechanism is developed based on matrix representation methodology starting from design behavior;

* Angular velocity and acceleration for chains 4, 7 and 10 graphically presented at Figure 3 for the equivalent model match with behavior of the original model of lathe with copier-blade mechanism shown at Figure 1 and are within the motion range of specific chain.
* The matrix representation methodology by a general matrix model at second level presents a good base for identification of many possible solutions, from which the desired one can be selected and also can e used for different models of mechanism.

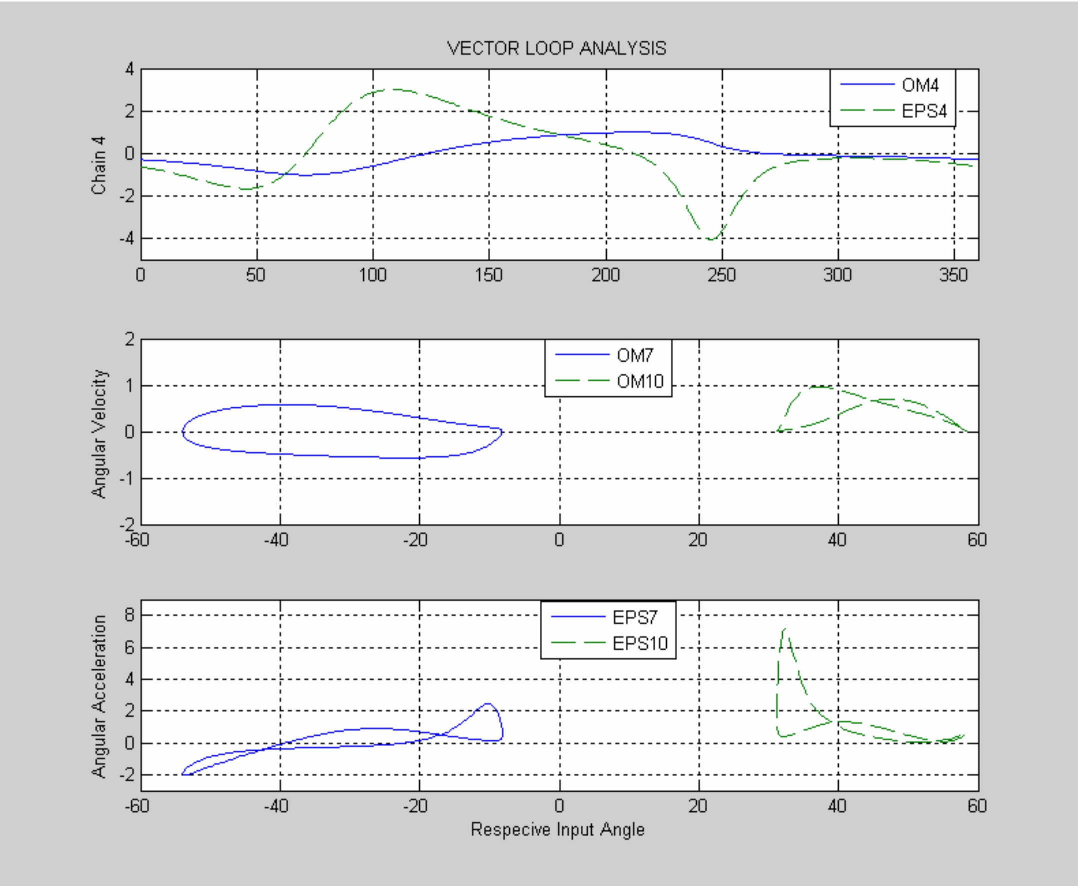

Figure 3. Kinematics analysis for chains 4, 7 and 10

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