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PRESENTATION OF EIGHT BASIC KINEMATIC BLOCKS WITH NONLINEAR MOTION CHARACTERISTICS DURING MECHANISMS DESIGN USING DUAL VECTOR ALGEBRA

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ABSTRACT
The concept of mechanisms design methodology includes the motion characteristics, and functional, topological and dimensional synthesis.
Functional synthesis selects the basic kinematic building blocks using the Motion Characteristic Code (MCC), while during topological synthesis the basic kinematics building blocks are assembled using dual-vector algebra.
From the data base of the 43 basic kinematics building blocks can be determined types of motion, relation between input-output motions and motion characteristics.
The representatives of eight types of the motions are analysed in this paper. Each basic kinematic building block is presented by Motion Characteristic Code, Screw Motion and its spatial orientation. The output motion characteristics for the Motion Characteristic Code is considered nonlinear for all kinematic blocks with types of motion: Rotation – Rotation, Rotational –Translation, Translation – Translation, Helical – Rotation.
Key words: Basic Kinematics Building Blocks, Motion Characteristic Code, Screw Motion.

1. INTRODUCTION
Mechanism design can be realised using several methodologies [1,2,9,10,11,12].
The methodology the algorithm that presents the mechanisms design using Basic Kinematics Blocks goes through four basic phases: (a) Motion Specifics, (b) Functional Synthesis, (c) Topological Synthesis and (d) Dimensional Synthesis [1,2]. In the motion specifics and functional synthesis the Motion Characteristic Code is taken into consideration, while at topological synthesis the methodology of dual-vector algebra is used [1].

2. METODOLOGY OF DUAL - VECTOR ALGEBRA
It is known that motion of any solid body in three-dimensional space can be represented through screw kinematic couples [1,4].
Screw can be defined by displacement and line. Line contains the information about position and direction of the motion. Displacement represents the transformation between rotational and translational motion. The motion transformation can be divided into a dual-number and dual-vector [1, 4, 7].

The final expression for screw motion for basic kinematics block is given as:

$$\hat{S} = (\alpha + \varepsilon a)\left[\begin{Bmatrix} l_x \\ l_y \\ l_z \end{Bmatrix} + \varepsilon \begin{Bmatrix} r_y l_z - r_z l_y \\ r_z l_x - r_x l_z \\ r_x l_y - r_y l_x \end{Bmatrix}\right] \quad (1)$$

3. METODOLOGY OF MOTION CHARACTERISTIC CODE (MCC)

Some authors, the motion in input and output of the kinematics block have used Motion Transformation Matrices of First Level (MTL[1]) and Operational Constraint Vector (OCV) [2, 3, 6, 10]. Similarly, in this paper Motion Characteristic Code (MCC) including data is used to determine the type of motion, continuity, linearity and direction of building blocks [1].
Motion Characteristic Code from can be described by:

$$MCC = (Motion\,Type, Continuity, Linearity, Direction) \quad (2)$$

Kinematics function for each building block is presented correctly through two Motion Characteristic Codes: the first one represents characteristics of input motion and the second one characteristics at output.

4. MOTION CHARACTERISTIC CODE (MCC), SCREW MOTION AND SPATIAL PRESENTATION FOR EIGHT BASIC KINEMATIC BLOCKS WITH NONLINEAR MOTION CHARACTERISTICS

Each basic kinematic building block is represented by Motion Characteristic Code, Screw Motion and its spatial orientation. The output motion characteristics for the Motion Characteristic Code is considered nonlinear for all kinematic blocks with types of motion: Rotation – Rotation, Rotational – Translation, Translation – Translation, Helical – Rotation. Each of kinematic couples have been represented by two representatives [1,4,8,9].

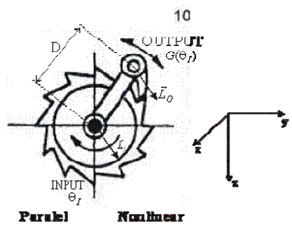
Pawl-Ratchet wheel

Input motion (0000):

$$\hat{S}_I = (\theta_I + \varepsilon \cdot 0)\left[\begin{Bmatrix} 0 \\ 0 \\ 1 \end{Bmatrix} + \varepsilon \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}\right].$$

Output motion (0110):

$$\hat{S}_O = (G(\theta_I) + \varepsilon \cdot 0)\left[\begin{Bmatrix} 0 \\ 0 \\ -1 \end{Bmatrix} + \varepsilon \begin{Bmatrix} 0 \\ D \\ 0 \end{Bmatrix}\right].$$



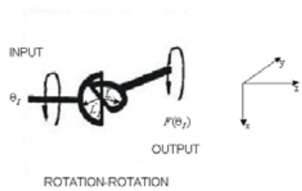
Universal-Joint

Input motion (0000):

$$\hat{S}_I = (\theta_I + \varepsilon \cdot 0)\left[\begin{Bmatrix} 0 \\ 0 \\ 1 \end{Bmatrix} + \varepsilon \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}\right].$$

Output motion (0000):

$$\hat{S}_O = (F(\theta_I) + \varepsilon \cdot 0)\left[\begin{Bmatrix} 0 \\ 1 \\ 0 \end{Bmatrix} + \varepsilon \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}\right].$$



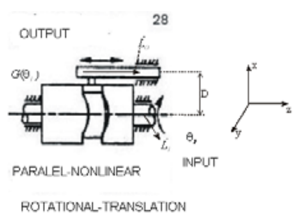
Cylindrical Cam-Follower

Input motion (0000):

$$\hat{S}_I = (\theta_I + \varepsilon \cdot 0)\left[\begin{Bmatrix} 0 \\ 0 \\ 1 \end{Bmatrix} + \varepsilon \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}\right].$$

Output motion (1010):

$$\hat{S}_O = (0 + \varepsilon \cdot G(\theta_I))\left[\begin{Bmatrix} 0 \\ 0 \\ 1 \end{Bmatrix} + \varepsilon \begin{Bmatrix} 0 \\ -D \\ 0 \end{Bmatrix}\right].$$



Wedge Cam-Follower

Input motion (0000):

$$\hat{S}_I = (\theta_I \quad + \quad \varepsilon \cdot 0)\left[\begin{Bmatrix}0\\0\\1\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\0\end{Bmatrix}\right].$$

Output motion (1010):

$$\hat{S}_O = (0 \quad + \quad \varepsilon \cdot D(\theta_I))\left[\begin{Bmatrix}0\\1\\0\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\D\end{Bmatrix}\right].$$

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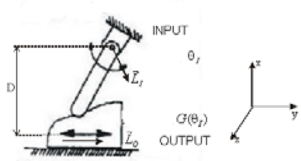

NORMAL-NONLINEAR

ROTATIONAL-TRANSLATION

Double-Slider

Input motion (1000):

$$\hat{S}_I = (0 \quad + \quad \varepsilon \cdot d_I)\left[\begin{Bmatrix}0\\0\\1\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\0\end{Bmatrix}\right].$$

Output motion (1010):

$$\hat{S}_O = (0 \quad + \quad \varepsilon \cdot F(d_I))\left[\begin{Bmatrix}0\\1\\0\end{Bmatrix} + \varepsilon\begin{Bmatrix}-D\\0\\0\end{Bmatrix}\right].$$

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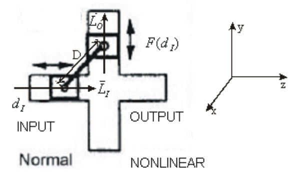

Normal NONLINEAR

TRANSLACION-TRANSLACION

Double-Slider

Input motion (1000):

$$\hat{S}_I = (0 \quad + \quad \varepsilon \cdot d_I)\left[\begin{Bmatrix}0\\0\\1\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\0\end{Bmatrix}\right].$$

Output motion (1010):

$$\hat{S}_O = (0 \quad + \quad \varepsilon \cdot F(d_I))\left[\begin{Bmatrix}0\\1\\0\end{Bmatrix} + \varepsilon\begin{Bmatrix}-D\\0\\0\end{Bmatrix}\right].$$

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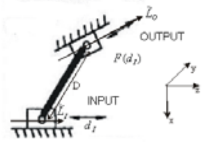

SKEW-NONLINEAR

TRANSLATION-TRANSLATION

Screw Bevel Gear

Input motion (2000):

$$\hat{S}_I = (\theta_I \quad + \quad \varepsilon \cdot 0)\left[\begin{Bmatrix}0\\0\\1\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\0\end{Bmatrix}\right].$$

Output motion (0010):

$$\hat{S}_O = (F(\theta_I) \quad + \quad \varepsilon \cdot 0)\left[\begin{Bmatrix}1\\0\\0\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\0\end{Bmatrix}\right].$$

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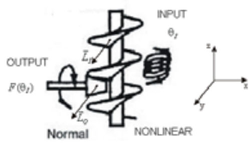

Normal NONLINEAR

HELICAL-ROTATION

Sprial Bevel Gear

Input motion (2000):

$$\hat{S}_I = (\theta_I \quad + \quad \varepsilon \cdot 0)\left[\begin{Bmatrix}0\\0\\1\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\0\end{Bmatrix}\right].$$

Output motion (0010):

$$\hat{S}_O = (F(\theta_I) \quad + \quad \varepsilon \cdot 0)\left[\begin{Bmatrix}0\\1\\0\end{Bmatrix} + \varepsilon\begin{Bmatrix}0\\0\\0\end{Bmatrix}\right].$$

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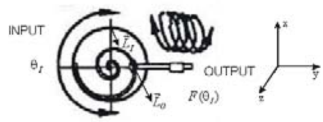

Normal NONLINEAR

HELICAL-ROTATION

5. CONCLUSIONS

Based on methodology for mechanisms design, the algorithm that uses Specific Motion, Functional Synthesis, Topological Synthesis and Dimensional Synthesis was applied in this study case including following phases:

- Topological Synthesis using Dual-Vector Algebra;
- Functional Synthesis using Motion Characteristic Code methodology;
- Design of different types of couples of mechanisms.

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