Analysis and Synthesis of Mechanisms with Bars and Gears Used in Robots and Manipulators

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Abstract: Bars and gears are used everywhere today, but a wide range of uses is robotics and mechatronics. Since ancient times, automations and mechanization have been used with mechanisms consisting of chains of bars and gears. These were obviously used for the purpose of transmitting the movement and its transformation, that is to say, as a mechanical transmission. Gear and bar automation are used today as modern mechanical transmissions, serial and parallel robots, machine building industry and all industrial areas where automation has penetrated. In fact, robotic gears and gears are the basis for mechanical transmissions to robots and at the same time have other roles such as balancing, support, etc. The most commonly used gears are tapered, conical gears, because they work faster, more dynamically, occupy less space, have fewer toothed gear teeth, low volume, light movement different directions and a multitude of features that make them irreplaceable within mobile mechanical systems. The gears and gears are increasingly used in the construction of manipulators and industrial robots, especially in the MOr. In the kinematic openings of Positioning Mechanisms (MPz) of the robots, also referred to as trajectory generators, a first kinematic chain with bars is attached, to which is attached a kinematic chain with cylindrical, conical and hypoid gears. The mechanical chains that can be made of conical mechanical transmissions and bars are complex, extremely complex and can work on different spaces and axes, with inclines and directional changes as desired. From this point of view, they can’t be replaced by other types of mechanical mechanisms or transmissions. A complex kinematic scheme with bevel gears and conical gears of a manipulator-robot with 6 + 1 mobilities is analyzed, where the positioning mechanism (RRR) is not distinguishable from the RRR orientation mechanism. The two kinematic chains of MPz (RzRxRx) and MOr (RzRxRxRxz) are staged (in extension). At the end (O6 point) of the articulated chain O0O1O2O3O4O5 the gripping mechanism (MAp), made with two articulated parallelograms, is attached. All 6 + 1 kinematic chains are operated by means of worm gear reducers with electric motors located at the base. The kinematic chain with bars is simplified to the left of Fig. 1 and to the right is an axial projection of the complete kinematic scheme of the gear with gears and gears. The articulated bars (0, 1, 2, 3, 4, 5, 6) with six movable elements are the main kinematic chain to which are attached six kinematic chains with conical gears.

Keywords: Anthropomorphic Robots, Kinematics, Bars and Gear, MPz Structure
Introduction

Today the moving mechanical systems are utilized in almost all vital sectors of humanity (Reddy et al., 2012). The robots are able to process integrated circuits (Aldana et al., 2013) sizes micro and nano, on which the man they can be seen only with electron microscopy (Lee, 2013). Dyeing parts in toxic environments, working in chemical and radioactive environments (Padula and Perdereau, 2013; Perumal and Jawahar, 2013), or at depths and pressures at the deep bottom of huge oceans, or conquest of cosmic space and visiting some new exoplanets, are with robots systems possible (Dong et al., 2013) and were turned into from the dream in reality (Garcia et al., 2007), because of use of mechanical platforms sequential gearbox (Cao et al., 2013; Petrescu et al., 2009). The man will be able to carry out its mission supreme (Tang et al., 2013; Tong et al., 2013), conqueror of new galaxies (de Melo et al., 2012), because of mechanical systems sequential gear-box (robotics systems) (Garcia-Murillo et al., 2013).

Robots were developed and diversified (Lin et al., 2013), different aspects (He et al., 2013), but today, they start to be directed on two major categories: Systems serial (Liu et al., 2013; Petrescu and Petrescu, 2011b) and parallel systems (Petrescu and Petrescu, 2012c); Parallel systems are more solid (Tabaković et al., 2013; Wang et al., 2013) but more difficult to designed and handled and for this reason, the serial systems were those which have developed the most. In medical operations or radioactive environments are preferred mobile systems parallel, because of their high accuracy positioning.

As examples of such combined mechanisms, several kinematic schemes of gears and gears can be observed, presented by Kojevnikov (1969; AUTORENKOLLEKTIV, 1968; Şaskin, 1963; 1971; Maros, 1958; Rehwald et al., 2000; 2001; Antonescu, 1993; 2003; Antonescu and Mateucă, 1989; Luck and Modler, 1995; Niemeyer, 2013), different aspects (He et al., 2013), but today, they start to be directed on two major categories: Systems serial (Liu et al., 2013; Petrescu and Petrescu, 2011b) and parallel systems (Petrescu and Petrescu, 2012c); Parallel systems are more solid (Tabaković et al., 2013; Wang et al., 2013) but more difficult to designed and handled and for this reason, the serial systems were those which have developed the most. In medical operations or radioactive environments are preferred mobile systems parallel, because of their high accuracy positioning.

The main problems with plane and spatial gears and gears refer to kinematic analysis and geometric-kinematic synthesis under certain conditions imposed by technological processes, Bruja and Dima (2001; Buda and Mateuca, 1989; Luck and Modler, 1995; Niemeyer, 2000; Tutunaru, 1969; Popescu, 1977; Braune, 2000; Dudita, 1989; Lichtenheldt, 1995; Lederer, 1993; Lin, 1999; Modler et al., 1998; 2001; Modler, 1979; Neumann, 1979; 2001; Stoica, 1977; Petrescu and Petrescu, 2011c-d; Petrescu, 2012d-e; 2016; 2017 a-q; Aversa et al., 2017 a-e; 2016a-o; Mirsayar et al., 2017; Petrescu and Petrescu, 2016a-c, 2013a-d, 2012a-d, 2011a-b; Petrescu, 2012a-c, 2009; Petrescu and Calautit, 2016a-b; Petrescu et al., 2016a-b; Maros, 1958; Modler and Wadewitz, 2001; Manolescu, 1968; Margine, 1999).

Materials and Methods

Bars and gears are used everywhere today, but a wide range of uses is robotics and mechatronics. Since ancient times, automatons and mechanization have been used with mechanisms consisting of chains of bars and gears. These were obviously used for the purpose of transmitting the movement and its transformation, that is to say, as a mechanical transmission. Gear and bar automation are used today as modern mechanical transmissions, serial and parallel robots, machine building industry and all industrial areas where automation has penetrated.

In fact, robotic gears and gears are the basis for mechanical transmissions to robots and at the same time have other roles such as balancing, support, etc. The most commonly used gears are tapered, conical gears, because they work faster, more dynamically, occupy less space, have fewer toothed gear teeth, low volume, light movement different directions and a multitude of features that make them irreplaceable within mobile mechanical systems.

The gears and gears are increasingly used in the construction of manipulators and industrial robots, especially in the MOr. In the kinematic openings of positioning mechanisms (MPz) of the robots, also referred to as trajectory generators, a first kinematic chain with bars is attached, to which is attached a kinematic chain with cylindrical, conical and hypoid gears.

The mechanical chains that can be made of conical mechanical transmissions and bars are complex, extremely complex and can work on different spaces and axes, with inclines and directional changes as desired. From this point of view, they can not be replaced by other types of mechanical mechanisms or transmissions.

A complex kinematic scheme (Fig. 1) with bevel gears and conical gears of a manipulator-robot with 6 + 1 mobilities is analyzed, where the positioning mechanism (RRR) is not distinguishable from the RRR orientation mechanism. The two kinematic chains of MPz (RzRxxRx) and MOr (RzRxRxRz) are staged (in extension). At the end (O6 point) of the articulated chain O0O1O2O3O4O5 the gripping mechanism (MAp), made with two articulated parallelograms, is attached.

All 6 + 1 kinematic chains are operated by means of worm gear reducers with electric motors located at the base (Fig. 1).

The kinematic chain with bars is simplified to the left of Fig. 1 and to the right is an axial projection of the complete kinematic scheme of the gear with gears and gears.

The articulated bars (0, 1, 2, 3, 4, 5, 6) with six movable elements are the main kinematic chain to which are attached six kinematic chains with conical gears (Petrescu and Petrescu, 2011c).

The mobility of the complex gear with bars and gears is calculated using the general formula (Antonescu, 2003):

\[ M = \sum_{k=1}^{6} (m \cdot C_k) - \sum_{r=2}^{6} (r \cdot N_r) \]  

(1)
Fig. 1: A complex kinematic scheme with bevel gears and conical gears of a manipulator-robot with 6 + 1 mobilities

The structural - geometric parameters of the complex mechanism are:

\[ m = 1, C_1 = 47; m = 2, C_2 = 27; m = 5, C_3 = 7; n = 45, r = 3, N_3 = 29; r = 6, N_6 = 7 \]

The total number of independent closed contours is calculated using the formula:

\[ N_c = \sum_{n=1}^{5} C_n - n = 47 + 27 + 7 - 45 = 36 \quad (2) \]

Of the 36 contours it identifies \( N_6 = 7 \) şi \( N_3 = 29 \), so from (1) it follows:

\[ M = (1 \cdot 47 + 2 \cdot 27 + 5 \cdot 7) - (3 \cdot 29 + 6 \cdot 7) = 7 \quad (3) \]

**Results**

**MPz Structure**

It is considered a RRR type RRR variant R || R || R (Fig. 2), which is the kinematic chain with bars, to which are attached two kinematic chains with r.d. conical.

The drive is made by electric motors placed on the base of one side of the open case.

The M1 engine, by means of a cylindrical gear, actuates the arm 1 which rotates about the fixed axis D1 (two coaxial bearings in the fixed housing are provided).

The M2 engine acts arm 2 through the kinematic chain attached to bar 1, consisting of two orthogonal conical gears.

The arm 2 rotates about the mobile axis \( \Delta_2 \), this movement being possible by means of two coaxial bearings mounted in the arm 1.

The M3 engine operates the bar 3 via the kinematic chain formed by four orthogonal conical gears.

The bar 3 rotates around the mobile axis \( \Delta_3 \), which is rotatable in two coaxial bearings mounted at the end of bar 2.

The mobility of the bars (arms) and the conical gears shall be calculated with the formula:

\[ M = C_1 + 2 \cdot C_2 - 3N_3 \quad (4) \]

Following the kinematic scheme of the complex mechanism with bars and toothed wheels (Fig. 2) the following structural-topological parameters are established:

\[ m = 1, C_1 = 10; m = 2, C_2 = 7; r = 3, n = 10, N_3 = 7 \quad (5) \]

With these numerical values, in formula (4) we obtain:

\[ M = 10 + 2 \cdot 7 - 3 \cdot 7 = 3 \quad (6) \]

According to the three mobilities, the actual movement of the mechanism is broken down into three
partial movements, so that in the operation of this complex mechanism three distinct phases can be followed, one for each mobility:

I. \( \alpha_1 \neq 0, \alpha_2 = 0, \alpha_3 = 0 \), i.e., the M1 engine is in operation and the other two M2 and M3 are locked. In this case, by actuating bar 1, the two lateral kinematic chains (with conical gears) are partially activated

II. \( \alpha_1 = 0, \alpha_2 \neq 0, \alpha_3 = 0 \), when M2 is in operation and M1 and M3 locked. In this phase, the other kinematic chain is also activated

III. \( \alpha_1 = 0, \alpha_2 = 0, \alpha_3 \neq 0 \), i.e., the M3 engine is in operation respectively M1 and M2 are blocked. In this situation, the movement from M3 does not influence the other two kinematic chains

The transmitting functions performed by the kinetic chains with conical gears shall be determined taking into account the following three unit analysis criteria:

a) In the conical gear, in which the rotational axes have chosen meanings (Fig. 3), the plus or minus sign is associated with the transmission ratio, as the common generator of the rolling cones is in the quadrants with the respective number (II and IV) respectively in odd-numbered quadrants (I and III)

b) In the case of a conical gear with moving axes, when the center wheel is fixed (Fig. 4), the relative rotation of the satellite wheel (relative to the mobile arm) is equal to the angular velocity of the arm, taken with the minus sign, multiplied by the transmission ratio the mobile to the fixed wheel in the "fixed arm" hypothesis

c) When two central wheels are in orthogonal conical gear with a satellite wheel (Fig. 5), if one of the central wheels is stationary, the other central wheel rotates twice with the angular speed of the harness:

**Criterion 1**

It is known that in the cylindrical gear (parallel axes) the transmission ratio is negative (external gearing) or positive (at the inner gearing)

To perform a unitary kinematic analysis, the convex ratio with fixed axes x and y (Fig. 3) is defined as an algebraic size.

The transmission ratio of a conical gear (with fixed axes) is uniquely defined by the general expression:

\[
i_{12} = \frac{\alpha_1}{\alpha_2} = (-1)^n \cdot \frac{z_2}{z_1}
\]

In quadrants I and III \((n = 1, 3)\) of (7), a negative size results (Fig. 3b).

In quadrants II and IV \((n = 2, 4)\) of (7) a positive value is obtained: (Fig. 3a).

**Criterion 2**

In the case of the conical gears with mobile axes (Fig. 4), this is a gear with gears and gears, in which the kinematic chain with bars \((0, 3)\) is attached to the kinematic chain with two conical wheels forming the conical gear \((1, 2)\).

Depending on the orientation of the rotation axes \((\Delta_1\) and \(\Delta_2)\) as coordinate axes \((x\) and \(y)\) of the two conical gears, the transmission ratio of the conical gear to the immobilized bar 3 has positive algebraic expression \(i_{23}^+ > 0\) (Fig. 4a) or negative \(i_{23}^- < 0\) (Fig. 4b).

The relative angular velocity of the wheel 2 relative to the bar 3 is calculated with the formula:

\[
\omega_{23} = (\alpha_1 - \alpha_3) \cdot i_{23}^- \text{ where } i_{23}^- = \frac{1}{i_{12}^+} \quad \text{(8)}
\]

If the center wheel 1 is immobilized by the lock \((\alpha_1 = 0)\), then the satellite wheel 2 rotates relative to the bar 3 at the relative angular velocity:

\[
\omega_{23} = -\alpha_3 \cdot i_{23}^+ \quad \text{(9)}
\]

![Fig. 3: The convex ratio with fixed axes x and y is defined as an algebraic size](image-url)
Criterion 3

In the kinematic schematics of conical gears and conical gears (Fig. 2), conically-shaped three-wheel kinematic chains are often attached to a kinematic chain with a single articulated bar (Fig. 5).

In the case of orthogonal conical gears (Fig. 5a), the central gears (1, 4) are equal and have the same number of teeth \( z_1 = z_4 \).

In the non-orthogonal conic gears (Fig. 5b) axes \( x \) and \( y \) divide the axial plane of the kinematic diagram into four quadrants and the two central wheels are not equal \( z_1 \neq z_4 \).

Write the transmission ratio between wheels 1 and 4 (Fig. 5) relative to bar 3, assuming that the rotation axes \( \Delta_2 \) are fixed:

\[
i_{34} = \frac{\omega_4 - \omega_3}{\omega_4 - \omega_5} = i_{12} \cdot i_{24} = -\frac{z_4}{z_1}
\]

(10)

For orthogonal gears (Fig. 5a) of (10) we deduce:

\[
i_{34} = \frac{\omega_4 - \omega_3}{\omega_4 - \omega_5} = -1
\]

(11)

When one of the central wheels is locked, for example wheel 4 \( (\omega_4 = 0) \), it is deduced from (11) that the other central wheel 1 rotates at an angular speed equal to twice the angular speed of the bar 3:

\[
\omega_1 = 2\omega_3
\]

(12)

In the kinematic analysis of the complex spatial mechanism (Fig. 2) the three angular velocities \( \omega_1, \omega_4 \) and \( \omega_6 \) are known. For a unitary calculation of the angular speeds of bars 1, 2 and 3, the first two criteria (1 and 2) apply.

Start the Phase III kinematic calculation when the M1 and M2 engines are locked, so the M3 engine drives the central kinematic chain 6-7 (7') - 8-9 (9') - 3 (3) without affecting the other.

The relative angular velocity of bar 3 relative to bar 2 is calculated in the assumption of fixed rotation axes, so bars 1 and 2 are immobilized:

\[
o\omega_3^0 = o_6 \cdot i_{34}^0
\]

(13)

The transmission function specific to this chain is explicitly written by applying criterion 1:
In phase II the M1 and M3 motors are locked and the M2 motor acts on the secondary cinematic chain on the 4-5 (5’) - 2’ (2) route. The movement of the bar 2 involves the activation of the gears (8,9) and (9’, 3’) which make the movement towards the immobilized wheel 7’.

The two motion streams in phase II allow the angular velocity to be calculated relative to the axis \( \Delta_2 \) of bar 2 from bar 1 (Fig. 2): \( \omega^0_{1\omega} = \omega_1 \cdot i_{1\omega} \) (15)

And at the \( \Delta_3 \) axis of bar 3 relative to bar 2, applying criterion 2 above: \( \omega^0_{2\omega} = -\omega_{2\omega} \cdot i_{2\omega} \) (16)

The transmission functions of formulas (15) and (16) are explicitly written, applying criterion 1:

\[
\begin{align*}
\dot{i}_{1\omega} &= i_{2\omega} \cdot i_{1\omega} = \left( \frac{z_y}{z_y} \right) \left( \frac{z_x}{z_x} \right) = -\frac{z_x \cdot z_y}{z_y \cdot z_x} \\
\dot{i}_{2\omega} &= i_{3\omega} \cdot i_{2\omega} = \left( \frac{z_z}{z_z} \right) \left( \frac{z_x}{z_x} \right) = \frac{z_x \cdot z_z}{z_z \cdot z_x} \\
\dot{i}_{3\omega} &= i_{4\omega} \cdot i_{3\omega} = \left( \frac{z_y}{z_y} \right) \left( \frac{z_z}{z_z} \right) = \frac{z_y \cdot z_z}{z_z \cdot z_y}
\end{align*}
\]

(17)  
(18)

Phase I is characterized by the blocking of the M2 and M3 engines and the M1 engine through the gear unit with the ratio \( i_1 \) acts on the bar 1, the angular speed of which is as follows:

\( \omega^0_1 = \omega_{1\omega} \cdot i_{1\omega} = \omega_1 \) (19)

The rotation of bar 1 determines partial additional movements in each of the other two kinematic chains (Fig. 2), resulting in the relative angular speeds of the bar 2 relative to 1 or the bar 3 relative to 2.

For the calculation of these relative angular speeds, criterion 2 is applied, knowing that central wheels 4 and 6 are stationary:

\( \omega_{21} = -\omega_1 \cdot i_{2\omega} \) (20)

Respectively:

\( \omega_{32} = -\omega_2 \cdot i_{3\omega} \) (21)

The transmission functions of formulas (20) and (21) are explained in (17) and (14) respectively, the explicit form being according to the teeth numbers:

\( \dot{i}_{1\omega} = \frac{z_x \cdot z_y}{z_y \cdot z_x} \) (22)

\[
\text{Respectively:}
\begin{align*}
\dot{i}_{2\omega} &= \frac{z_x \cdot z_y \cdot z_y}{z_y \cdot z_x \cdot z_y} \\
\dot{i}_{3\omega} &= \frac{z_y \cdot z_z}{z_z \cdot z_y}
\end{align*}
\]

The general case is when all three engines M1, M2 and M3 are started, which corresponds to the overlapping of the three phases analyzed above.

It is of interest in calculating the rotations and angular speeds of the kinematic chain bars 1, 2 and 3 (Fig. 2).

For bar 1, the angular velocity is given by formula (19) and for bar 2 the relative angular velocity relative to the \( \Delta_2 \) axis is calculated by summing the expressions (20) and (15):

\[
\begin{align*}
\omega_1 &= \omega_{1\omega} + \omega_{21} = -\omega_{2\omega} \cdot i_{2\omega} \\
\omega_{2\omega} &= \omega_1 - \omega_{2\omega} \cdot i_{2\omega} \\
\omega_{3\omega} &= \omega_{2\omega} - \omega_3 \cdot i_{3\omega} = \omega_{2\omega} - \omega_{2\omega} \cdot i_{3\omega}
\end{align*}
\]

(24)

Discussion

It is considered a RRR type RRR variant R || R || R (Fig. 2), which is the kinematic chain with bars, to which are attached two kinematic chains with r.d. conical.

The drive is made by electric motors placed on the base of one side of the open case.

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II. , when M2 is in operation and M1 and M3 locked. In this phase, the other kinematic chain is also activated
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**Conclusion**

The gears and gears are increasingly used in the construction of manipulators and industrial robots, especially in the MOR. In the kinematic openings of positioning mechanisms (MPz) of the robots, also referred to as trajectory generators, a first kinematic chain with bars is attached, to which is attached a kinematic chain with cylindrical, conical and hypoid gears. The mechanical chains that can be made of conical mechanical transmissions and bars are complex, extremely complex and can work on different spaces and axes, with inclines and directional changes as desired. From this point of view, they can’t be replaced by other types of mechanical mechanisms or transmissions. A complex kinematic scheme with bevel gears and conical gears of a manipulator-robot with 6 + 1 mobilities is analyzed, where the positioning mechanism (RMR) is not distinguishable from the RRR orientation mechanism. The two kinematic chains of MPz (RzRxxRx) and MOR (RzRxRxRz) are staged (in extension). At the end (O6 point) of the articulated chain O0O1O2O3O4O5 the gripping mechanism (MAP), made with two articulated parallelograms, is attached. All 6 + 1 kinematic chains are operated by means of worm gear reducers with electric motors located at the base. The kinematic chain with bars is simplified to the left of Fig. 1 and to the right is an axial projection of the complete kinematic scheme of the gear with gears and gears. The articulated bars (0, 1, 2, 3, 4, 5, 6) with six movable elements are the main kinematic chain to which are attached six kinematic chains with conical gears.

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**Author’s Contributions**

This section should state the contributions made by each author in the preparation, development and publication of this manuscript.
Ethics

Authors should address any ethical issues that may arise after the publication of this manuscript.

References

Aldana, N.D., C.L. Trujillo and J.G. Guarnizo, 2013. Active and reactive power flow regulation for a grid connected vsc based on fuzzy controllers. Revista Facultad de Ingenieria, 66: 118-130.

Antonescu, P. and M. Mitraș, 1989. Contributions to the synthesis of the mechanisms used as windshield wipers. SYROM'89, Bucharest, 4: 23-32.

Aversa, R., R.V.V. Petrescu, B. Akash, R.B. Bucinell and A. Apicella, 2016d. Biomechanically inspired shape memory effect machines driven by muscle like acting NiTi alloys. Am. J. Eng. Applied Sci., 9: 1096-1105.

Aversa, R., F.I.T. Petrescu, R.V. Petrescu and A. Apicella, 2016a. Physiologic human fluids and swelling behavior of hydrophilic biocompatible hybrid ceramo-polymeric materials. Am. J. Eng. Applied Sci., 9: 962-972.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016b. Glassy amorphous metal injection molded induced morphological defects. Am. J. Applied Sci., 13: 1476-1482.

Aversa, R., R.V. Petrescu, F.I.T. Petrescu, M. Neacsu et al., 2016e. Present a mechatronic system having able to determine the concentration of carotenoids. Am. J. Biochem. Biotechnol.

Aversa, R., D. Parcesepe, R.V. Petrescu, G. Chen and F.I.T. Petrescu et al., 2016.6. Glassy amorphous metal injection molded induced morphological defects. Am. J. Applied Sci., 13: 1264-1271.

Aversa, R., F.I.T. Petrescu, R.V. Petrescu and A. Apicella, 2016a. Biomimetic FEA bone modeling for customized hybrid biological prostheses development. Am. J. Applied Sci., 13: 1060-1067. DOI: 10.3844/ajeassp.2016.1060.1067

Aversa, R., F.I.T. Petrescu, R.V. Petrescu and A. Apicella, 2016b. Flexible stem trabecular prostheses. Am. J. Eng. Applied Sci., 9: 1213-1221.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016a. Mitochondria are naturally micro robots-a review. Am. J. Eng. Applied Sci., 9: 991-1002.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016j. We are addicted to vitamins C and E-A review. Am. J. Eng. Applied Sci., 9: 1003-1018.

Aversa, R., F.I.T. Petrescu, A. Apicella and F.I.T. Petrescu, 2016m. Physiologic human fluids and swelling behavior of hydrophilic biocompatible hybrid ceramo-polymeric materials. Am. J. Eng. Applied Sci., 9: 962-972.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016b. One can slow down the aging through antioxidants. Am. J. Eng. Applied Sci., 9: 1112-1126.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016m. About homeopathy or Similia similibus curantur. Am. J. Eng. Applied Sci., 9: 1164-1172.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016n. The basic elements of life's. Am. J. Eng. Applied Sci., 9: 1189-1197.

Aversa, R., R.V. Petrescu, A. Apicella, I.T.F. Petrescu and J.K. Calautit et al., 2017c. Something about the V engines design. Am. J. Applied Sci., 14: 34-52.

Aversa, R., R.V. Petrescu, B. Akash, R.B. Bucinell and J.M. Corchado et al., 2017b. Kinematics and forces to a new model forging manipulator. Am. J. Applied Sci., 14: 60-80.
de Melo, F.L., S.F.R. Alves and J.M. Rosário, 2012. Mobile robot navigation modelling, control and applications. Int. Rev. Modelling Simulations, 5: 1059-1068.

Dong, H., N. Giakoumidis, N. Figueiroa and N. Mavridis, 2013. Approaching behaviour monitor and vibration indication in developing a General Moving Object Alarm System (GMOAS). Int. J. Advanced Robotic Syst., 10: 1-12. DOI: 10.5772/56586

Dudita, F.L., 1989. Articulated, Inventive, Cinematic Mechanisms. 1st Edn., Technical Publishing House, Bucharest.

Garcia, E., M.A. Jimenez, P.G. De Santos and M. Armada, 2007. The evolution of robotics research. IEEE Robotics Automation Magazine, 14: 90-103.

Garcia-Murillo, M., J. Gallardo-Alvarado and E. Castillo-Castaneda, 2013. Finding the generalized forces of a series-parallel manipulator. Int. J. Adv. Robotic Syst., 10: 1-10. DOI: 10.5772/53824

He, B., Z. Wang, Q. Li, H. Xie and R. Shen, 2013. An analytical method for the kinematics and dynamics of a multiple-backbone continuum robot. Int. J. Adv. Robotic Syst., 10: 1-13. DOI: 10.5772/54051

Kojevikov, S.N., 1969. Teoria mehanizmov i mašin. 1st Edn., Izd. Mašinostroenie, Moskva.

Lederer, P., 1993. Dynamische synthese der übertragungs-funktion eines Kurvengetriebes. In: Mechanism and Machine Theory, Flores, P. (Ed.), Elsevier, Great Britain, pp: 23-29.

Lee, B.J., 2013. Geometrical derivation of differential kinematics to calibrate model parameters of flexible manipulator. Int. J. Adv. Robotic Syst., 10: 1-9. DOI: 10.5772/5592

Lichtenheldt, W., 1995. Konstruktionslehre der Getriebe. 1st Edn., Akademie – Verlag Berlin, Germany.

Lin, S., 1999. Getriebesynthese nach unscharfen lagenvorgaben durch positionierung eines vorbestimmten getriebes. Fortschnitt – Berichte VDI, Reihe 1. Nr. 313, Düsseldorf: VDI – Verlage.

Lin, W., B. Li, X. Yang and D. Zhang, 2013. Modelling and control of inverse dynamics for a 5-DOF parallel kinematic polishing machine. Int. J. Adv. Robotic Syst., 10: 1-21. DOI: 10.5772/54966

Liu, H., W. Zhou, X. Lai, and S. Zhu, 2013. An efficient inverse kinematic algorithm for a PUMA560-structured robot manipulator. Int. J. Adv. Robotic Syst., 10: 1-5. DOI: 10.5772/56403

Luck, K., K.H. Modler, 1995. Getriebelehre – Analyse, Synthese, Optimierung. 2. 1st Edn., Aufl. Berlin/ Heidelberg/ Springer, New York.

Manolescu, N.I., 1968. Problems of Machine Theory and Machines. 1st Edn., E.D.P., Bucharest.

Margine, A.L., 1999. Contributions to the geometric-kinematical and dynamic synthesis of planetary gears with cylindrical gears. PhD thesis, Pontifical Bolivarian University, Colombia.

Maros, D., 1958. Gear Wheel Kinematic. 1st Edn., Technical Publishing House, Bucharest.

Mirsayar, M.M., V.A. Joneidi, R.V.V. Petrescu, F.I.T. Petrescu and F. Berto, 2017. Extended MTSN criterion for fracture analysis of soda lime glass. Eng. Fracture Mech., 178: 50-59. DOI: 10.1016/j.engfracmech.2017.04.018

Modler, K.H. and C. Wadewitz, 2001. Synthese von Raderkoppelgetriebe als Vorschaltgetriebe mit definierter Ungleichförmigkeit. Wissenschaftliche Zeitschrift, TU-Dresden Nr. 3.

Modler, K.H., 1979. Reaklisierung Von Pilgerschritten Durch Zweiraderkoppel-Getriebe. 1st Edn., Dynamik und Getriebetechnik, A, Dresda, Germany.

Modler, K.H., C. Wadewitz and U. Trepte, 1998. Rechnergestützte synthese von raderkoppelgetrieben als vorschaltgetriebe zur erzeugung nichtlinearer antriebsbewegungen. Bericht zum DFG – Vorhaben Mo 537/5 – 1. TU Dresden.

Neumann, R., 1979. Einstellbare Raderkoppelgetriebe. 1st Edn., Dynamik und Getriebetechnik, A, Dresda.

Neumann, R., 2001. Dreiraderkoppel – schrittgetriebe mit zahnradern oder zahnriemen. SYROM’2001, Bucureştip.

Niemeyer, J., 2000. Das IGM – Getriebewikik – Wissensverarbeitung in der Getriebetechnik mit Hilfe der Internet – Technologie. In: IMG – Kolloquium Getriebetechnik 2000, Forschung & Lehre 1972-2000, Dittrich, G. (Edn.), Aachen: Mainz, pp: 53-66.

Padula, F. and V. Perdereau, 2013. An on-line path planner for industrial manipulators. Int. J. Adv. Robotic Syst., 10: 1-12. DOI: 10.5772/55063

Perumail, S. and N. Jawahar, 2013. Automated trajectory planner of industrial robot for pick-and-place task. Int. J. Adv. Robotic Syst., 10: 1-17. DOI: 10.5772/53940

Petrescu, RV., R. Aversa, B. Akash, B. Feng and A. Bagherinejad, 2017a. Modern propulsions for aerospace-a review. J. Aircraft Spacecraft Technol., 1: 1-8.

Petrescu, RV., R. Aversa, B. Akash, B. Feng and A. Bagherinejad, 2017b. Modern propulsions for aerospace-part II. J. Aircraft Spacecraft Technol., 1: 9-17.

Petrescu, F.I. and J.K. Calautit, 2013a. Finding the generalized forces of a multiple-backbone continuum robot. Int. J. Adv. Robotic Syst., 10: 1-17. DOI: 10.5772/56945

Petrescu, F.I. and J.K. Calautit, 2016. Project HARP. J. Aircraft Spacecraft Technol., 5: 124.

Petrescu, F.I. and J.K. Calautit, 2016b. About the light dimensions. Am. J. Applied Sci., 13: 321-325. DOI: 10.3844/ajassp.2016.321.325

Petrescu, F.I. and R.V. Petrescu, 2011a. Memories about Flight. 1st Edn., CreateSpace, pp: 652.

Petrescu, F.I. and R.V. Petrescu, 2011b. Mechanical Systems, Serial and Parallel. 1st Edn., LULU Publisher, London, UK, ISBN-10: 1446600394, pp: 124.
Popescu, I., 1977. Design of planar mechanisms. 1st Edn., Scrisul Românesc Publishing House of Craiova, CreateSpace Publisher, USA, ISBN-13: 978-1468030419.

Reddy, P., K.V. Shihabudheen, and J. Jacob, 2012. Precise non linear modeling of flexible link flexible joint manipulator. IReMoS, 5: 1368-1374.

Rehwald, W. and K. Luck, 2000. Kosim – Koppelgetriebesimulation. In: Fortschritt Berichte VDI, Reihe 1, Nr. 332. Dusseldorf: VDI Verlag.

Rehwald, W. and K. Luck, 2001. Betrachtungen zur Zahl der Koppelgetriebetypen. Wissenschaftliche Zeitschrift der TU Dresda, 50: 107-115.

Şaskin, A.G., 1963. Sintezu Zubciato - riciajnih mehanizmov s vâstoem. Teoria mašin I mehanizmov, Moskva, 94-95: 88-110.

Şaskin, A.G., 1971. Zubciato riciajni mehanizmi. Izd. Mašinostroenie, Moskva.

Stoica, I.A., 1977. Gear wheel interference. 1st Edn., DACIA Publishing House, Cluj-Napoca.

Tabaković, S., M. Zeško, R. Gatalo and A. Živković, 2013. Program suite for conceptual designing of parallel mechanism-based robots and machine tools. Int. J. Adv. Robotic Syst., 10: 1-13. DOI: 10.5772/56633

Tang, X., D. Sun and Z. Shao, 2013. The structure and dimensional design of a reconfigurable PKM. Int. J. Adv. Robotic Syst., 10: 1-10. DOI: 10.5772/54696

Tong, G., J. Gu, and W. Xie, 2013. Virtual entity-based rapid prototype for design and simulation of humanoid robots. Int. J. Adv. Robotic Syst., 10: 1-9. DOI: 10.5772/55936

Tutunaru, D., 1969. Rectangular and inverse planar mechanisms. 1st Edn., Technical Publishing House, Bucharest.

Wang, K., M. Luo, T. Mei, J. Zhao, and Y. Cao, 2013. Dynamics analysis of a three-DOF planar serial-parallel mechanism for active dynamic balancing with respect to a given trajectory. Int. J. Adv. Robotic Syst., 10: 1-10. DOI: 10.5772/54201

**Source of Figures**

Petrescu and Petrescu, 2011c.