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Original Research Paper

Serial, Anthropomorphic, Spatial, Mechatronic Systems can be Studied More Simply in a Plan

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Abstract: The mobile, mechatronic, robotic, serial, spatial, anthropomorphic type systems, which are currently the most used in the machine building industry, can be studied much more simply in a plan instead of the usual spatial study. This not only simplifies the understanding of these systems (including from a didactic point of view) but also facilitates computational methods, moving from matrix analytical methods to more simple classical methods. Usage is done by conversion, so nothing is lost from the essence of physic-mathematical phenomena. The idea of moving from spatial to planar study has been centered over time on all major mechanisms when it was possible, precisely for ease of calculation and working methods, but also for a better understanding of physical phenomena. The vast majority of classical mechanisms can be treated as they move in most cases into a master plan. This is the case with known mechanical transmissions, classic motors of all types, working mechanisms, engine or lucrative cars, etc. In anthropomorphic robots, the method is no longer used because they work clearly in a well-defined space. We used the idea to divide this space into a main work plan that can rotate around a main axis so that the study of all movements is done in the workplan and then the rotations of these parameters corresponding to the rotation of the work plane around the main axis of rotation. The physical-mathematical methods are greatly simplified in this way, from matrix difficult calculations to simple, classical analytical calculation methods.

Keywords: Anthropomorphic Robots, Kinematics, 3D calculation, 2D calculation

Introduction

The mobile, mechatronic, robotic, serial, spatial, anthropomorphic type systems, which are currently the most used in the machine building industry, can be studied much more simply in a plan instead of the usual spatial study. This not only simplifies the understanding of these systems (including from a didactic point of view), but also facilitates computational methods, moving from matrix analytical methods to more simple classical methods. Usage is done by conversion, so nothing is lost from the essence of physic-mathematical phenomena. The idea of moving from spatial to planar study has been centered over time on all major mechanisms when it was possible, precisely for ease of calculation and working methods, but also for a better understanding of physical phenomena. The vast majority of classical mechanisms can be treated as they move in most cases into a master plan. This is the case with known mechanical transmissions, classic motors of all types, working mechanisms, engine or lucrative cars, etc. In anthropomorphic robots, the method is no longer used because they work clearly in a well-defined space. We used the idea to divide this space into a main work plan that can rotate around a main axis so that the study of all movements is done in the workplan and then the rotations of these parameters corresponding to the rotation of the work plane around the main axis of rotation. The physical-mathematical methods are greatly simplified in this way, from matrix difficult calculations to simple, classical analytical calculation methods.

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; Perumaal 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 Mitrache, 1989).

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 (2001; Buda and Mateucă, 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; Modler and Wadewitz, 2001; Modler, 1979; Neumann, 1979; 2001; Stoica, 1977; Petrescu and Petrescu, 2011c-d; Petrescu, 2012d-e; Petrescu, 2016; Petrescu *et al*., 2017a-q; Aversa *et al*., 2017a-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

Figure 1 shows the geometric-kinematic scheme of a base structure 3R.

From this platform you can study by adding any other modern n-R scheme.

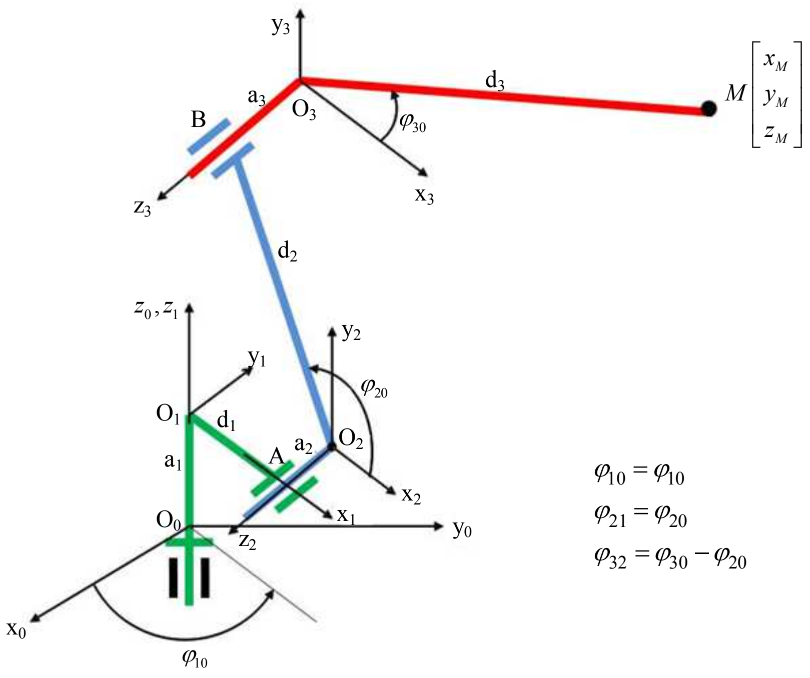

Fig. 1: The geometric-kinematic scheme of a base structure 3R

The platform (system) of Fig. 1 has three degrees of mobility, made by three actuators (electric motors) or actuators. The first electric motor trains the entire system in a rotation motion around a vertical axis O0z0. The motor (actuator) number 1 is mounted on the fixed member (bay, 0) and drives the mobile element 1 in a rotation motion around a vertical axis. On the mobile element 1, then all the other components (components) of the system are built.

There follows a planar (vertical) cinematic chain consisting of two movable elements and two kinematic motor couplings. It is the movable kinematic elements 2 and 3, the assembly 2,3 being moved by the second actuator mounted in the coupling A fixed on the element 1. Thus the second electric motor fixed by the element 1 will drive the element 2 in a relative rotation relative to element 1, but automatically it will move the entire kinematic chain 2-3.

The last actuator (electric motor) fixed by element 2 in B will rotate element 3 (relative to 2).

The rotation φ_{10} made by the first actuator is also relative (between elements 1 and 0) and absolute (between elements 1 and 0).

The rotation φ_{20} of the second actuator is also relative (between elements 2 and 1) and absolute (between elements 2 and 0) due to the positioning of the system.

The rotation $\varphi=\varphi_{32}$ of the third actuator is only relative (between elements 3 and 2), the corresponding absolute (between elements 3 and 0) being a function of $\varphi=\varphi_{32}$ and φ_{20}.

The kinematic chain 2-3 (made up of moving kinematic elements 2 and 3) is a planar cinematic chain that falls into one plane or one or more parallel planes. It is a special cinematic system that will be studied separately. The kinematic coupler A (O2) and B (O3) become the first fixed coupler and the second movable coupler, both of which are C5 cinematic couplers, of rotation.

In order to determine the degree of mobility of the planar kinematic chain 2-3, the structural formula given by relation (1), where m represents the number of movable elements of the planar kinematic chain, in our case m = 2 (with respect to the two moving kinematic elements 2 and 3) and C5 represents the number of fifth order kinematic couplings, in the present case C5 = 2 (with the A and B or O2 and O3 couplings):

$$M_3 = 3\cdot m - 2\cdot C_5 = 3\cdot 2 - 2\cdot 2 = 6 - 4 = 2 \tag{1}$$

The kinematic chain 2-3 having the degree of mobility 2 must be driven by two motors.

It is preferred that the two actuators are two electric, DC, or alternating motors. The action can also be done with other engines. Hydraulic, pneumatic, sonic, etc.

The schematic diagram of the planar kinematic chain 2-3 (Fig. 2) resembles its kinematic scheme.

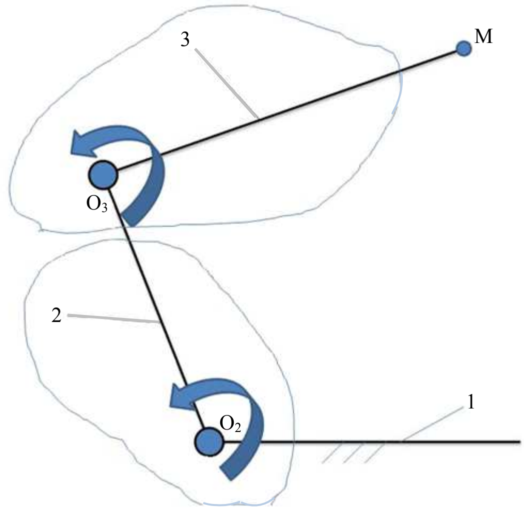

Fig. 2: The schematic diagram of the planar kinematic chain 2-3 bound to the element 1 considered to be fixed

The guide element 2 is connected to the fixed element 1 by the motor coupler O2 and the drive element 3 is connected to the mobile element 2 by the motor coupler O3.

This results in a two-degree open cinematic chain made by the two actuators, ie the two electric motors mounted in the kinematic couplers A and B or O2 or O3.

Results; Direct Kinematics of the Plan 2-3

Figure 3 shows the kinematic diagram of the open 2-3 chain (Petrescu, 2014).

The kinematic parameters φ_{20} and φ_{30} are known in kinematics and must be determined by analyzing the parameters xM and yM, which represent the scaled coordinates of the point M (endefactor M).

The d2 + d3 vectors are projected onto the Cartesian axis system considered fixed, xOy, identical to x2O2y2. The system of scalar equations is obtained (2):

$$\begin{cases} x_{2M} \equiv x_M = x_{O_3} + x_{3M} = d_2\cdot\cos\phi_{20} + d_3\cdot\cos\phi_{30} = d\cdot\cos\phi \\ y_{2M} \equiv y_M = y_{O_3} + y_{3M} = d_2\cdot\sin\phi_{20} + d_3\cdot\sin\phi_{30} = d\cdot\sin\phi \end{cases} \tag{2}$$

After determining the cartesian coordinates of the M point using the relations given by the system (2), the parameters of the angle can be obtained immediately using the relations established within the system (3):

$$\begin{cases} d^2 = x_M^2 + y_M^2 \\ d = \sqrt{x_M^2 + y_M^2} \\ \cos\phi = \dfrac{x_M}{d} = \dfrac{x_M}{\sqrt{x_M^2 + y_M^2}} \\ \sin\phi = \dfrac{y_M}{d} = \dfrac{y_M}{\sqrt{x_M^2 + y_M^2}} \\ \phi = sign(\sin\phi)\cdot\arccos(\cos\phi) \end{cases} \tag{3}$$

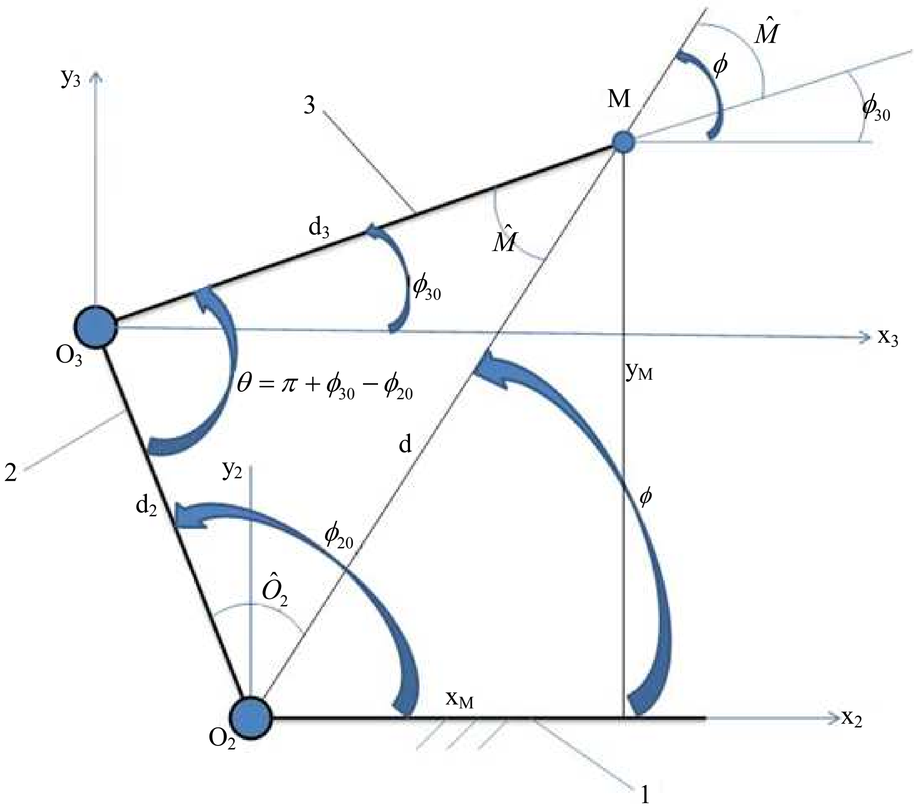

Fig. 3: The kinematic scheme of the planar kinematic chain 2-3 bound to element 1 considered fixed

The system (2) is written more concise in the time-dependent form (4), resulting in the speed system (5), which derives from time, in turn generates the acceleration system (6):

$$\begin{cases} x_M = d_2 \cdot \cos\phi_{20} + d_3 \cdot \cos\phi_{30} \\ = d_2 \cdot \cos\phi_{20} + d_3 \cdot \cos(\theta + \phi_{20} - \pi) \\ y_M = d_2 \cdot \sin\phi_{20} + d_3 \cdot \sin\phi_{30} \\ = d_2 \cdot \sin\phi_{20} + d_3 \cdot \sin(\theta + \phi_{20} - \pi) \end{cases} \quad (4)$$

$$\begin{cases} v_M^x \equiv \dot{x}_M = -d_2 \cdot \sin\phi_{20} \cdot \omega_{20} - d_3 \cdot \sin\phi_{30} \cdot \omega_{30} \\ = -d_2 \cdot \sin\phi_{20} \cdot \omega_{20} - d_3 \cdot \sin\phi_{30} \cdot (\dot{\theta} + \omega_{20}) \\ v_M^y \equiv \dot{y}_M = d_2 \cdot \cos\phi_{20} \cdot \omega_{20} + d_3 \cdot \cos\phi_{30} \cdot \omega_{30} \\ = d_2 \cdot \cos\phi_{20} \cdot \omega_{20} + d_3 \cdot \cos\phi_{30} \cdot (\dot{\theta} + \omega_{20}) \end{cases} \quad (5)$$

$$\begin{cases} a_M^x \equiv \ddot{x}_M = -d_2 \cdot \cos\phi_{20} \cdot \omega_{20}^2 - d_3 \cdot \cos\phi_{30} \cdot \omega_{30}^2 \\ = -d_2 \cdot \cos\phi_{20} \cdot \omega_{20}^2 - d_3 \cdot \cos\phi_{30} \cdot (\dot{\theta} + \omega_{20})^2 \\ a_M^y \equiv \ddot{y}_M = -d_2 \cdot \sin\phi_{20} \cdot \omega_{20}^2 - d_3 \cdot \sin\phi_{30} \cdot \omega_{30}^2 \\ = -d_2 \cdot \sin\phi_{20} \cdot \omega_{20}^2 - d_3 \cdot \sin\phi_{30} \cdot (\dot{\theta} + \omega_{20})^2 \end{cases} \quad (6)$$

Note: The angular speeds of the actuators were considered constant (relations 7):

$$\begin{aligned} &\dot{\phi}_{20} = \omega_{20} = ct; \dot{\theta} = ct \Rightarrow si\omega_{30} = ct \\ &\text{Is considered}\, \varepsilon_{20} = \ddot{\theta} = \varepsilon_{30} = 0 \end{aligned} \quad (7)$$

Relationships (3) are also derived and the velocity (8) and acceleration (9) systems are obtained:

$$\begin{cases} d^2 = x_M^2 + y_M^2 \\ 2 \cdot d \cdot \dot{d} = 2 \cdot x_M \cdot \dot{x}_M + 2 \cdot y_M \cdot \dot{y}_M \\ d \cdot \dot{d} = x_M \cdot \dot{x}_M + y_M \cdot \dot{y}_M \\ \dot{d} = \dfrac{x_M \cdot \dot{x}_M + y_M \cdot \dot{y}_M}{d} \\ d \cdot \cos\phi = x_M \\ d \cdot \sin\phi = y_M \\ \dot{d} \cdot \cos\phi - d \cdot \sin\phi \cdot \dot{\phi} = \dot{x}_M \mid \cdot(-\sin\phi) \\ \dot{d} \cdot \sin\phi + d \cdot \cos\phi \cdot \dot{\phi} = \dot{y}_M \mid \cdot(\cos\phi) \\ \overline{\hphantom{xxxxxxxxxxxxxxxxxxxx}} \\ d \cdot \dot{\phi} = \dot{x}_M \cdot (-\sin\phi) + \dot{y}_M \cdot (\cos\phi) \\ \dot{\phi} = \dfrac{\dot{y}_M \cdot \cos\phi - \dot{x}_M \cdot \sin\phi}{d} \\ \overline{\hphantom{xxxxxxxxxxxxxxxxxxxx}} \\ \dot{d} = \dfrac{x_M \cdot \dot{x}_M + y_M \cdot \dot{y}_M}{d} \end{cases} \quad (8)$$

$$
\begin{cases}
d^2 = x_M^2 + y_M^2 \\
2 \cdot d \cdot \dot{d} = 2 \cdot x_M \cdot \dot{x}_M + 2 \cdot y_M \cdot \dot{y}_M \\
d \cdot \dot{d} = x_M \cdot \dot{x}_M + y_M \cdot \dot{y}_M \\
\dot{d}^2 + d \cdot \ddot{d} = \dot{x}_M^2 + x_M \cdot \ddot{x}_M + \dot{y}_M^2 + y_M \cdot \ddot{y}_M \\
\ddot{d} = \dfrac{\dot{x}_M^2 + x_M \cdot \ddot{x}_M + \dot{y}_M^2 + y_M \cdot \ddot{y}_M - \dot{d}^2}{d} \\
d \cdot \cos\phi = x_M \\
d \cdot \sin\phi = y_M \\
\dot{d} \cdot \cos\phi - d \cdot \sin\phi \cdot \dot{\phi} = \dot{x}_M \mid \cdot(-\sin\phi) \\
\dot{d} \cdot \sin\phi + d \cdot \cos\phi \cdot \dot{\phi} = \dot{y}_M \mid \cdot(\cos\phi) \\
\rule{8cm}{0.4pt} \\
d \cdot \dot{\phi} = -\dot{x}_M \cdot \sin\phi + \dot{y}_M \cdot \cos\phi \\
\dot{d} \cdot \dot{\phi} + d \cdot \ddot{\phi} = \ddot{y}_M \cdot \cos\phi - \dot{y}_M \cdot \sin\phi \cdot \dot{\phi} \\
-\ddot{x}_M \cdot \sin\phi - \dot{x}_M \cdot \cos\phi \cdot \dot{\phi} \\
\ddot{\phi} = \dfrac{\ddot{y}_M \cdot \cos\phi - \ddot{x}_M \cdot \sin\phi - \dot{y}_M \cdot \sin\phi \cdot \dot{\phi} - \dot{x}_M \cdot \cos\phi \cdot \dot{\phi} - \dot{d} \cdot \dot{\phi}}{d} \\
\rule{8cm}{0.4pt} \\
\ddot{d} = \dfrac{\dot{x}_M^2 + x_M \cdot \ddot{x}_M + \dot{y}_M^2 + y_M \cdot \ddot{y}_M - \dot{d}^2}{d}
\end{cases}
\tag{9}
$$

Next, positions, speeds and accelerations will be determined, depending on the scaled positions of point O3. Start from the scaled coordinates of point O3 (10):

$$
\begin{cases}
x_{O_3} = d_2 \cdot \cos\phi_{20} \\
y_{O_3} = d_2 \cdot \sin\phi_{20}
\end{cases}
\tag{10}
$$

The scaling speeds and the O3 point accelerations are then determined by successive derivation of the system (10), in which the d.cos or d.sin products are replaced by the respective positions, xO3 or yO3, which thus become variables (a see relations 11 and 12):

$$
\begin{cases}
\dot{x}_{O_3} = -d_2 \cdot \sin\phi_{20} \cdot \omega_{20} = -y_{O_3} \cdot \omega_{20} \\
\dot{y}_{O_3} = d_2 \cdot \cos\phi_{20} \cdot \omega_{20} = x_{O_3} \cdot \omega_{20}
\end{cases}
\tag{11}
$$

$$
\begin{cases}
\ddot{x}_{O_3} = -d_2 \cdot \cos\phi_{20} \cdot \omega_{20}^2 = -x_{O_3} \cdot \omega_{20}^2 \\
\ddot{y}_{O_3} = -d_2 \cdot \sin\phi_{20} \cdot \omega_{20}^2 = -y_{O_3} \cdot \omega_{20}^2
\end{cases}
\tag{12}
$$

The scalar speeds and accelerations of the O3 point were made according to the initial positions (scaling) and the absolute angular velocity of the element 2. The angular velocity was considered constant.

Discussion

The technique of determining velocities and accelerations according to positions is extremely useful in the study of system dynamics, vibrations and noise caused by the system. This technique is common in studying system vibrations. The vibrations of the scalar positions of point O3 are known and the vibrations of the speeds and accelerations of that point as well as other points of the system are readily determined as a function of the known scaling positions of the O3 point. It is also possible to calculate the local noise levels at different points of the system as well as the overall noise level generated by the system with a sufficiently large approximation compared to the noise obtained by experimental measurements with the appropriate equipment. The study of system dynamics can also be developed by this technique.

The absolute speed of the O3 point (speed module) is given by the relationship (13):

$$
\begin{aligned}
v_{O_3} &= \sqrt{\dot{x}_{O_3}^2 + \dot{y}_{O_3}^2} \\
&= \sqrt{d_2^2 \cdot \omega_{20}^2 \cdot \sin^2\phi_{20} + d_2^2 \cdot \omega_{20}^2 \cdot \cos^2\phi_{20}} \\
&= \sqrt{d_2^2 \cdot \omega_{20}^2} = d_2 \cdot \omega_{20}
\end{aligned}
\tag{13}
$$

The absolute acceleration of the O3 point for constant angular velocity is given by the relationship (14):

$$
\begin{aligned}
a_{O_3} &= \sqrt{\ddot{x}_{O_3}^2 + \ddot{y}_{O_3}^2} \\
&= \sqrt{d_2^2 \cdot \omega_{20}^4 \cdot \cos^2\phi_{20} + d_2^2 \cdot \omega_{20}^4 \cdot \sin^2\phi_{20}} \\
&= \sqrt{d_2^2 \cdot \omega_{20}^4} = d_2 \cdot \omega_{20}^2
\end{aligned}
\tag{14}
$$

The scalar kinematic parameters of the M point, endefactor, will also be determined, depending on the position parameters of the O3 and M points (relational systems 15-17):

$$
\begin{cases}
x_M = x_{O_3} + d_3 \cdot \cos\phi_{30} \\
y_M = y_{O_3} + d_3 \cdot \sin\phi_{30} \\
d_3 \cdot \cos\phi_{30} = x_M - x_{O_3} \\
d_3 \cdot \sin\phi_{30} = y_M - y_{O_3}
\end{cases}
\tag{15}
$$

$$
\begin{cases}
\dot{x}_M = \dot{x}_{O_3} - d_3 \cdot \sin\phi_{30} \cdot \dot{\phi}_{30} \\
= -y_{O_3} \cdot \omega_{20} + \left(y_{O_3} - y_M\right) \cdot \left(\omega_{20} + \dot{\theta}\right) \\
= y_{O_3} \cdot \dot{\theta} - y_M \cdot \left(\omega_{20} + \dot{\theta}\right) \\
= (y_{O_3} - y_M) \cdot \dot{\theta} - y_M \cdot \omega_{20} \\
\dot{y}_M = \dot{y}_{O_3} + d_3 \cdot \cos\phi_{30} \cdot \dot{\phi}_{30} \\
= x_{O_3} \cdot \omega_{20} + \left(x_M - x_{O_3}\right) \cdot \left(\omega_{20} + \dot{\theta}\right) \\
= x_M \cdot \left(\omega_{20} + \dot{\theta}\right) - x_{O_3} \cdot \dot{\theta} \\
= \left(x_M - x_{O_3}\right) \cdot \dot{\theta} + x_M \cdot \omega_{20} \\
\dot{y}_{O_3} - \dot{y}_M = -d_3 \cdot \cos\phi_{30} \cdot \left(\omega_{20} + \dot{\theta}\right) \\
\dot{x}_M - \dot{x}_{O_3} = -d_3 \cdot \sin\phi_{30} \cdot \left(\omega_{20} + \dot{\theta}\right)
\end{cases}
\tag{16}
$$

$$\begin{cases} \ddot{x}_M = \left(\dot{y}_{O_3} - \dot{y}_M\right) \cdot \dot{\theta} - \dot{y}_M \cdot \omega_{20} \\ \ddot{y}_M = \left(\dot{x}_M - \dot{x}_{O_3}\right) \cdot \dot{\theta} + \dot{x}_M \cdot \omega_{20} \\ \dot{y}_{O_3} - \dot{y}_M = \left(x_{O_3} - x_M\right) \cdot \left(\omega_{20} + \dot{\theta}\right) \\ \dot{x}_M - \dot{x}_{O_3} = \left(y_{O_3} - y_M\right) \cdot \left(\omega_{20} + \dot{\theta}\right) \\ \ddot{x}_M = \left(x_{O_3} - x_M\right) \cdot \left(\omega_{20} + \dot{\theta}\right) \cdot \dot{\theta} \\ + \left(x_{O_3} - x_M\right) \cdot \dot{\theta} \cdot \omega_{20} - x_M \cdot \omega_{20}^2 \\ \ddot{y}_M = \left(y_{O_3} - y_M\right) \cdot \left(\omega_{20} + \dot{\theta}\right) \cdot \dot{\theta} \\ + \left(y_{O_3} - y_M\right) \cdot \dot{\theta} \cdot \omega_{20} - y_M \cdot \omega_{20}^2 \\ \ddot{x}_M = 2 \cdot \left(x_{O_3} - x_M\right) \cdot \dot{\theta} \cdot \omega_{20} \\ + \left(x_{O_3} - x_M\right) \cdot \dot{\theta}^2 - x_M \cdot \omega_{20}^2 \\ \ddot{y}_M = 2 \cdot \left(y_{O_3} - y_M\right) \cdot \dot{\theta} \cdot \omega_{20} \\ + \left(y_{O_3} - y_M\right) \cdot \dot{\theta}^2 - y_M \cdot \omega_{20}^2 \\ \ddot{x}_M = \left(x_{O_3} - x_M\right) \cdot \left(2 \cdot \dot{\theta} \cdot \omega_{20} + \dot{\theta}^2\right) - x_M \cdot \omega_{20}^2 \\ \ddot{y}_M = \left(y_{O_3} - y_M\right) \cdot \left(2 \cdot \dot{\theta} \cdot \omega_{20} + \dot{\theta}^2\right) - y_M \cdot \omega_{20}^2 \\ \ddot{x}_M = \left(x_{O_3} - x_M\right) \cdot \left(\omega_{20} + \dot{\theta}\right)^2 - x_{O_3} \cdot \omega_{20}^2 \\ \ddot{y}_M = \left(y_{O_3} - y_M\right) \cdot \left(\omega_{20} + \dot{\theta}\right)^2 - y_{O_3} \cdot \omega_{20}^2 \end{cases} \quad (17)$$

Conclusion

The mobile, mechatronic, robotic, serial, spatial, anthropomorphic type systems, which are currently the most used in the machine building industry, can be studied much more simply in a plan instead of the usual spatial study.

This not only simplifies the understanding of these systems (including from a didactic point of view), but also facilitates computational methods, moving from matrix analytical methods to more simple classical methods.

Usage is done by conversion, so nothing is lost from the essence of physic-mathematical phenomena. The idea of moving from spatial to planar study has been centered over time on all major mechanisms when it was possible, precisely for ease of calculation and working methods, but also for a better understanding of physical phenomena.

The vast majority of classical mechanisms can be treated as they move in most cases into a master plan. This is the case with known mechanical transmissions, classic motors of all types, working mechanisms, engine or lucrative cars, etc.

In anthropomorphic robots, the method is no longer used because they work clearly in a well-defined space. We used the idea to divide this space into a main work plan that can rotate around a main axis so that the study of all movements is done in the workplan and then the rotations of these parameters corresponding to the rotation of the work plane around the main axis of rotation.

The physical-mathematical methods are greatly simplified in this way, from matrix difficult calculations to simple, classical analytical calculation methods.

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3. Contract research. GR 69/10.05.2007: NURC in 2762; theme 8: Dynamic analysis of mechanisms and manipulators with bars and gears
4. Labor contract, no. 35/22.01.2013, the UPB, "Stand for reading performance parameters of kinematics and dynamic mechanisms, using inductive and incremental encoders, to a Mitsubishi Mechatronic System" "PN-II-IN-CI-2012-1-0389"

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 Ingeniería, 66: 118-130.

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

Antonescu, P., 1993. Synthesis of Manipulators. 1st Edn., Lito UPB, Bucureşti.

Antonescu, P., 2003. Mecanisms. 1st Edn., Ed. Printech, Bucureşti.

AUTORENKOLLEKTIV, 1968. Getriebetechnik-VEB. 1st Edn., Verlag technik, Berlin, Germany.

Aversa, R., D. Parcesepe, R.V. Petrescu, G. Chen and F.I.T. Petrescu *et al*., 2016b. Glassy amorphous metal injection molded induced morphological defects. Am. J. Applied Sci., 13: 1476-1482.

Aversa, R., D. Parcesepe, R.V.V. Petrescu, F. Berto and G. Chen *et al*., 2017d. Process ability of bulk metallic glasses. Am. J. Applied Sci., 14: 294-301.

Aversa, R., E.M. Buzea, R.V. Petrescu, A. Apicella and M. Neacsa *et al*., 2016e. Present a mechatronic system having able to determine the concentration of carotenoids. Am. J. Eng. Applied Sci., 9: 1106-1111.

Aversa, R., F. Tamburrino, R.V. Petrescu, F.I.T. Petrescu and M. Artur *et al*., 2016d. Biomechanically inspired shape memory effect machines driven by muscle like acting NiTi alloys. 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/ajassp.2016.1060.1067

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

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016i. 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., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016k. 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, 2016l. 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 curentur≫. 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.

Aversa, R., R.V. Petrescu, F.I.T. Petrescu and A. Apicella, 2016c. Smart-factory: Optimization and process control of composite centrifuged pipes. Am. J. Applied Sci., 13: 1330-1341.

Aversa, R., R.V. Petrescu, F.I.T. Petrescu and A. Apicella, 2016h. Biomimetic and evolutionary design driven innovation in sustainable products development. Am. J. Eng. Applied Sci., 9: 1027-1036.

Aversa, R., R.V. Petrescu, R. Sorrentino, F.I.T. Petrescu and A. Apicella, 2016f. Hybrid ceramo-polymeric nanocomposite for biomimetic scaffolds design and preparation. Am. J. Eng. Applied Sci., 9: 1096-1105.

Aversa, R., R.V.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2017a. Nano-diamond hybrid materials for structural biomedical application. Am. J. Biochem. Biotechnol.

Aversa, R., R.V.V. Petrescu, B. Akash, R.B. Bucinell and J.M. Corchado *et al*., 2017e. Something about the balancing of thermal motors. Am. J. Eng. Applied Sci., 10: 200.217. DOI: 10.3844/ajeassp.2017.200.217

Aversa, R., V. Perrotta, R.V. Petrescu, C. Misiano and F.I.T. Petrescu *et al*., 2016g. From structural colors to super-hydrophobicity and achromatic transparent protective coatings: Ion plating plasma assisted TiO2 and SiO2 Nano-film deposition. Am. J. Eng. Applied Sci., 9: 1037-1045.

Braune, R., 2000. Bewegungsdesign – Eine Kernkompetenz des Getriebe Technikers. VDI – Berichte Nr. 1567, Dusseldorf: VDI – Verlag.

Bruja, A. and M. Dima, 2001. Synthesis of kinematics of harmonics reducers with rigid front element. 6th Simp. Nat. Construction Machinery, 1: 53-59.

Buda, L. and C. Mateucă, 1989. Functional, cinematic and cinetostatic analysis of the lifting mechanism of the passenger carriages. SYROM'89, Bucharest, 4: 59-66.

Cao, W., H. Ding, Z. Bin and C. Ziming, 2013. New structural representation and digital-analysis platform for symmetrical parallel mechanisms. Int. J. Adv. Robotic Syst., 10: 1-11. DOI: 10.5772/56380

de Melo, F.L., A.S.F. Reis and J.M. Rosário, 2012. Mobile robot navigation modelling, control and applications. Int. Rev. Modelling Simulations, 5: 1059-1068.

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

Dudita, 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 analytic method for the kinematics and dynamics of a multiple-backbone continuum robot. Int. J. Adv. Robotic Syst., 10: 1-13. DOI: 10.5772/54051

Kojevnikov, S.N., 1969. Teoria Mehanizmov I Maşin. 1st Edn., Izd. Maşinostroenie, Moskva.

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

Lee, B.J., 2013. Geometrical derivation of differential kinematics to calibrate model parameters of flexible manipulator. Int. J. Advanced Robotic Sys., 10: 1-9. DOI: 10.5772/55592

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

Lin, S., 1999. Getriebesynthese nach unscharfen Lagenvorgaben durch Positionierung eines vorbestimmten Getriebes. Fortschritt – Berichte VDI, Reihe 1. Nr. 313, Dusseldorf: 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. and K.H. Modler, 1995. Getriebetechnik – Analyse, Synthese, Optimierung. 2nd Edn., Aufl. Berlin/ Heidelberg/ New York: Springer.

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

Margine, AL., 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 Mechan., 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 Ungleichformigkeit.1st Edn., Wissenschaftliche Zeitschrift, TU-Dresden Nr. 3.

Modler, K.H., 1979. Reakisierung Von Pilgerschritten Durch Zweiraderkoppel-Getriebe. 1st Edn., Dynamik und Getribetechnik, A, Dresda.

Modler, K.H., C. Wadewitz and U. Trepte, 1998. Rechnergestutzte 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 Getribe-Technik, A, Dresda.

Neumann, R., 2001. Dreiraderkoppel – schrittgetriebe mit zahnradern oder zahnriemen. SYROM'2001, Bucureşti, 3: 321-324.

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

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

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

Petrescu, F.I.T., 2009. New aircraft. Proceedings of the 3rd International Conference on Computational Mechanics, Oct. 29-30, Brasov, Romania.

Petrescu, F.I., B. Grecu, A. Comanescu and R.V. Petrescu, 2009. Some mechanical design elements. Proceedings of the International Conference on Computational Mechanics and Virtual Engineering, (MEC'09), Braşov, pp: 520-525.

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-13: 978-1-4466-0039-9, pp: 124.

Petrescu, FIT. and RV. Petrescu, 2011c. Planetary Trains. 1st Edn., CreateSpace Publisher, USA, ISBN-13: 978-1468030419, pp: 204.

Petrescu, F.I. and R.V. Petrescu, 2011d. Dynamics of Distribution Mechanisms. 1st Edn., Create Space Publisher, USA, ISBN-13; 978-1-4680-5265-7, pp: 188.

Petrescu, F.I.T., 2012a. Cold Nuclear Fusion. 1st Edn., Create Space, USA, ISBN-13: 1478234261, pp: 80.

Petrescu, F.I.T., 2012b. Particle Annihilation-A source of renewable energy?

Petrescu, F.I.T., 2012c. Particle annihilation-a source of renewable energy? Infinite Energy J.

Petrescu, F.I., 2012d. Basis of Analysis and Optimization of Rigid Memory Systems - Course and Applications. 1st Edn., Create Space Publisher, USAISBN-13: 978-1-4700-2436-9, pp: 164.

Petrescu, F.I., 2012e. Theory of Mechanisms - Course and Applications. 2nd Edn., Create Space Publisher, USA, ISBN-13: 978-1-4792-9362-9, pp: 284.

Petrescu, R.V. and F.I.T. Petrescu, 2012a. Northrop. Books on Demand, ISBN-13: 978-3848209323, pp: 142.

Petrescu, F.I. and R.V. Petrescu, 2012b. New Aircraft II. 1st Edn., Books on Demand, pp: 138.

Petrescu, F.I. and R.V. Petrescu, 2012c. Mecatronica-Sisteme Seriale Si Paralele.1st Edn., Create Space Publisher, USA, ISBN-13: 978-1-4750-6613-5, pp: 128.

Petrescu, F.I. and R.V. Petrescu, 2012d. Kinematics of the planar quadrilateral mechanism. Engevista, 14: 345-348.

Petrescu, R.V. and F.I. Petrescu, 2013a. Lockheed Martin. 1st Edn., CreateSpace, pp: 114.

Petrescu, R.V. and F.I. Petrescu, 2013b. Northrop. 1st Edn., CreateSpace, pp: 96.

Petrescu, R.V. and F.I. Petrescu, 2013c. The Aviation History or New Aircraft I Color. 1st Edn., CreateSpace, pp: 292.

Petrescu, F.I. and R.V. Petrescu, 2013d. Cinematics of the 3R Dyad. Engevista, 15: 118-124.

Petrescu, F.I.T., 2014. Sisteme Mecatronice Seriale, Paralele si Mixte. 1st Edn., Create Space Publisher, ISBN-10: 1495923819, pp: 224.

Petrescu, FIT., 2016. Valorisation of Romanian-Romanian Engineering Tradition. 1st Edn., Create Space Publisher, USA, ISBN-13: 9781537177984.

Petrescu, F.I. and R.V. Petrescu, 2016a. Parallel moving mechanical systems kinematics. Engevista, 18:455-491.

Petrescu, F.I. and R.V. Petrescu, 2016b. Direct and inverse kinematics to the anthropomorphic robots. Engevista, 18: 109-124.

Petrescu, F.I. and R.V. Petrescu, 2016c. Dynamic cinematic to a structure 2R. Revista Geintec-Gestao Inovacao E Tecnol., 6: 3143-3154.

Petrescu, F.I.T. and J.K. Calautit, 2016a. About Nano fusion and dynamic fusion. Am. J. Applied Sci., 13: 261-266.

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, R.V.V., R. Aversa, A. Apicella, F. Berto and S. Li *et al.*, 2016a. Ecosphere protection through green energy. Am. J. Applied Sci., 13: 1027-1032.

Petrescu, F.I.T., A. Apicella, R.V.V. Petrescu, S.P. Kozaitis and R.B. Bucinell *et al.*, 2016b. Environmental protection through nuclear energy. Am. J. Applied Sci., 13: 941-946.

Petrescu, RV., R. Aversa, B. Akash, R. Bucinell and J. Corchado *et al.*, 2017a. Modern propulsions for aerospace-a review. J. Aircraft Spacecraft Technol., 1: 1-8.

Petrescu, RV., R. Aversa, B. Akash, R. Bucinell and J. Corchado et al., 2017b. Modern propulsions for aerospace-part II. J. Aircraft Spacecraft Technol., 1: 9-17.

Petrescu, RV., R. Aversa, B. Akash, R. Bucinell and J. Corchado *et al.*, 2017c. History of aviation-a short review. J. Aircraft Spacecraft Technol., 1: 30-49.

Petrescu, RV., R. Aversa, B. Akash, R. Bucinell and J. Corchado *et al.*, 2017d. Lockheed martin-a short review. J. Aircraft Spacecraft Technol., 1: 50-68.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017e. Our universe. J. Aircraft Spacecraft Technol., 1: 69-79.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017f. What is a UFO? J. Aircraft Spacecraft Technol., 1: 80-90.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017g. About bell helicopter FCX-001 concept aircraft-a short review. J. Aircraft Spacecraft Technol., 1: 91-96.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017h. Home at Airbus. J. Aircraft Spacecraft Technol., 1: 97-118.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017i. Airlander. J. Aircraft Spacecraft Technol., 1: 119-148.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017j. When boeing is dreaming – a review. J. Aircraft Spacecraft Technol., 1: 149-161.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017k. About northrop grumman. J. Aircraft Spacecraft Technol., 1: 162-185.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017l. Some special aircraft. J. Aircraft Spacecraft Technol., 1: 186-203.

Petrescu, RV., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017m. About helicopters. J. Aircraft Spacecraft Technol., 1: 204-223.

Petrescu, RV., R. Aversa, B. Akash, F. Berto and A. Apicella *et al.*, 2017n. The modern flight. J. Aircraft Spacecraft Technol.

Petrescu, RV., R. Aversa, B. Akash, F. Berto and A. Apicella *et al.*, 2017o. Sustainable energy for aerospace vessels. J. Aircraft Spacecraft Technol.

Petrescu, RV., R. Aversa, B. Akash, F. Berto and A. Apicella *et al.*, 2017p. Unmanned helicopters. J. Aircraft Spacecraft Technol.

Petrescu, RV., R. Aversa, B. Akash, F. Berto and A. Apicella *et al.*, 2017q. Project HARP. J. Aircraft Spacecraft Technol.

Popescu, I., 1977. Design of Planar Mechanisms. 1st Edn., Scrisul Românesc Publishing House of Craiova.

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. Fortschritt Berichte VDI, Reihe 1, Nr. 332. Dusseldorf: VDI Verlag.

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

Şaskin, A.G., 1963. Sintezu zubciato - rîciajnîh mehanizmov s vâstoem. Teoria maşin I mehanizmov, Moskva, 94-95:. 88-110.

Şaskin, A.G., 1971. Zubciato Rîciajnîe Mehanizmî. 1st Edn., Izd. Maşinostroenie, Moskva.

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

Tabaković, S., M. Zeljković, R. Gatalo and A. Zivković, 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

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Petrescu, 2014.