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Current Stage in the Field of Mechanisms with Gears and Rods

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Abstract: The development and diversification of machines and mechanisms with applications in all fields require new scientific researches for the systematization and improvement of existing mechanical systems by creating new mechanisms adapted to modern requirements, which involve increasingly complex topological structures. The modern industry, the practice of designing and building machinery is increasingly based on the results of scientific and applied research. Each industrial achievement has backed theoretical and experimental computer-assisted research, which solves increasingly complex problems with advanced computing programs using an increasingly specialized software. The robotization of technological processes determines and influences the emergence of new industries, applications under special environmental conditions, the approach of new types of technological operations, manipulation of objects in the alien space, teleoperators in the top disciplines like medicine, robots covering a whole field Greater service provision in our modern, computerized society. In this context, the present paper attempts to make a scientific and technical contribution to the kinematic analysis and geometric - kinematic synthesis of gears and gears, both as plane and spatial structures. By definition, these complex mechanisms are composed of bars and lever mechanisms (gears and racks). A remarkable problem with the use of conical gears is the spherical coupling design through three-axis spherical gear mechanisms. This modeling is extremely useful in the construction and kinematics of robots, especially the orientation mechanisms, which explains the particular interest in the use of gears and gears. The cinematic study methods of complex gears with bars and gears are particularly diverse, but a unitary method allows the adaptation and use of more efficient analytical and numerical resolution algorithms. The beginning of the use of gears and gears should be sought in ancient Egypt at least a thousand years before Christ. Here, for the first time, spur gears were used for crop irrigation and worm gears for cotton processing.

Keywords: Mechanism, Applied Computing, Algorithm, Machines and Mechanisms, Gears and Rods

Introduction

The development and diversification of machines and mechanisms with applications in all fields requires new scientific researches for the systematization and improvement of existing mechanical systems by creating new mechanisms adapted to modern requirements, which involve increasingly complex topological structures.

The modern industry, the practice of designing and building machinery is increasingly based on the results of scientific and applied research.

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In this context, the present paper attempts to make a scientific and technical contribution to the kinematic analysis and geometric - kinematic synthesis of gears and gears, both as plane and spatial structures.

By definition, these complex mechanisms are composed of bars and lever mechanisms (gears and racks).

Only mechanisms with rigid kinematic elements were considered, both the bars and the toothed wheels being considered undeformable.

During the elaboration of this paper, the following requirements were considered:

- Performing a unitary work on documenting and personal scientific contributions
- The synthetic way of presenting the different aspects analyzed
- Highlighting the outstanding achievements of researchers and mechanics specialists
- The creation of a high-level scientific work, but with the possibility of being traced easily by specialists
- To formulate conclusions to fix what is essential and to generate new ideas

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The cinematic study methods of complex gears with bars and gears are particularly diverse, but a unitary method allows the adaptation and use of more efficient analytical and numerical resolution algorithms.

The beginning of the use of gears and gears should be sought in ancient Egypt at least a thousand years before Christ.

Here, for the first time, spur gears were used for crop irrigation and worm gears for cotton processing.

230 years BC, in the city of Alexandria in Egypt, a multi-lever wheel was used and a rack gear.

Also, planetary gears with satellite gears have been used since the time of the 100-80 BC, to an ancient Greek astrolab.

This ingenious mechanism displays the movement of the sun and the moon with the help of dozens of gears of different sizes, the movement of which came from a single cinematic input element.

The transmission of gear with gears has seen substantial progress since 1300 AD, when the Italian master Giovani da Dondi made an astronomical horology, composed of internal gears and elliptical gears.

In the fifteenth century, Leonardo da Vinci laid the foundations for modern cinematics and dynamics, stating, among other things, the principle of superposition of independent movements.

This principle of the summation of independent movements will be applied successfully, in the present paper, to the analysis and kinematic synthesis of the complex mechanisms with multi mobile gears and bars.

The first gear adjustable gears were used in 1769 by Cugnot to equip the first vehicle propelled by a steam engine.

Between 1778 and 1784, J. Watt designed and built a new steam machine (Dudita, 1989; Watt steam engine, From Wikipedia) with a double-acting piston, in which the alternative translational movement of the piston is transformed into a continuous and uniform rotation of a steering wheel. In order to transform the oscillating rotation motion of the rocker in a continuous rotary motion of the crank, the Watt has created several distinct mechanisms, including the planetary gear with cylindrical gears.

The Englishman E. Cartwright created and patented in 1800 a rectilinear guiding mechanism with symmetrically placed bars and gears for the purpose of transforming the movement of the piston (steam driven) into rotation of the steering wheel.

During the same period, at the beginning of the 19th century, another Englishman, J. White, discovered that the rectilinear guidance of a point can be done with a planetary cylindrical mechanism with an internal gear, which generates a particular degenerated right hippoccillus.

At the end of the 19th century, in 1886, German Carl Benz made the first three-wheeled motor propelled by a thermal engine with a horizontally placed cylinder.

Since the flywheel has a vertical spindle, a conical gear has been used to convey the engine torque from the flywheel to the propulsion wheels.

In the twentieth century, with the modern industrial development, textile and metallurgical machines, packaging machines and, more recently, industrial manipulators and robots, the transmission of the rotation between shafts with varying axle spacing appears necessary.

Often, it is required that the uninterrupted and uniform rotation of the drive shaft will result in reversible rotation of the driven shaft, movement with stops during the given limit, motion in the pilgrim step, etc.

In a series of machines and robot manipulators, it is necessary to obtain complex trajectories of some points of the elements, which can't be obtained with the help of ordinary bars.

Such technical requirements can be satisfied if gears with gears and gears are used.

For this purpose, mechanisms can be constructed in which bar systems and toothed wheel systems are (in parallel, overlapped) and the elements of the bar mechanism bear on their sprocket wheels axes.

There are also complex gears with bars and gears, in which the gears are parts of the general structural scheme.

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 and Luck, 2000; 2001), Antonescu (1993; 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 and Dima (2011), 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 and Wadewitz (1998; 2001; Modler, 1979), Neumann (1979; 2001), Stoica (1977), Petrescu and Petrescu (2011c; 2011d; Petrescu, 2012d; 2012e); (Petrescu, 2016; Petrescu *et al.*, 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; Aversa *et al.*, 2017a; 2017b; 2017c; 2017d; 2017e; 2016a; 2016b; 2016c; 2016d; 2016e; 2016f; 2016g; 2016h; 2016i; 2016j; 2016k; 2016l; 2016m; 2016n; 2016o; Mirsayar *et al.*, 2017; Petrescu and Petrescu, 2016a; 2016b; 2016c; 2013a; 2013b; 2013c; 2013d, 2012a; 2012b; 2012c; 2012d, 2011a; 2011b; Petrescu, 2012a; 2012b; 2012c, 2009; Petrescu and Calautit, 2016a; 2016b; Petrescu *et al.*, 2016a; 2016b).

Materials and Methods

Research on Cinematic Analysis of Rods and Gears Mechanisms

The most representative schools of mechanics that have developed and initiated theoretical and practical scientific research in the field of rods and gears were the German school (K. Hoecken, W. Jahr, P. Knechtel, K. Hain, W. Mayer zur Cappellen, W. Rath, O. Tolle, J. Volmer, R. Neumann, W. Rehwald, K. Luck, KH Modler) and Russian (SO Dobrogurski, II Artobolevski, SN Kojevnikov, LB Maisiuk, SA Cerkudinov, AS Saskin).

In Fig. 1a is shown (Dudita, 1989; Petrescu and Petrescu, 2011c; 2011d; Petrescu, 2012d; 2012e) the mechanism with geared wheel driven z_3 whose motion is transmitted from geared wheel z_2 on the cradle c of the quadrilateral mechanism. Wheel z_2 engages with wheel z_1 which rotates with respect to an eccentric axis.

Depending on the correlated dimensions of the bar elements and the number of teeth of the z_3 geared wheel to the output shaft, the rotation obtained may be continuous (uninterrupted) with a degree of unevenness, stop motion, partial forward movement (pilgrimage step) Fig. 1b.

In Fig. 2, there are shown a few schematic of rods and gears constructed on the basis of the four-tiered bar mechanism, whose driven toothed wheels rotate around the fixed axis of the rocker and the drive is made from the crank a.

Various combinations of bar mechanisms and gears with circular and non-circular wheels can be built in a very large number, but a small number of all practical variants are used.

In connection with the above we consider only 2 types of gears and gears, namely: The mechanisms for transmitting the rotation between shafts with the variable distance between the axes and the mechanisms used to obtain the complex-looking trajectories and the transformation of the movement.

From the point of view of the structural elements, all wheel and ring gears with circular wheels can be regarded as series chains with the variable configuration of the center line, variation which determines the position of the elements, of the axes of the non-essential gears.

It may be that the transmission of the movement from the toothed wheel of the chain to another toothed wheel element of the neighboring member is accomplished only if the toothed wheel or toothed wheel of the group has an axis superimposed with the axis of the joint formed by these bars.

In the general case, the beam and gear mechanism can be considered to have 2 or more mobility.

As an example of multi mobile mechanism with bars and gears, the kinematic scheme of Fig. 3a is considered; this mechanism has 3 mobilities.

Thus, the angular velocity of any of the wheels can be determined if the angular speeds of bars a and b and one of the gears are required.

The number of mobilities and therefore the number of leading elements can be reduced if the elements are joined together. For example, if the wheel 1 is connected to the base and the wheel 2 with the element b, the mono mobile mechanism (Fig. 3b) is obtained, in which the wheels 2 and 3 do not rotate with respect to bar b, but the point C describes what Called epicycloid elongated. Such a mechanism is also called the "dyad train" (Maros, 1958; Modler and Wadewitz, 2001; Manolescu, 1968; Margine, 1999).

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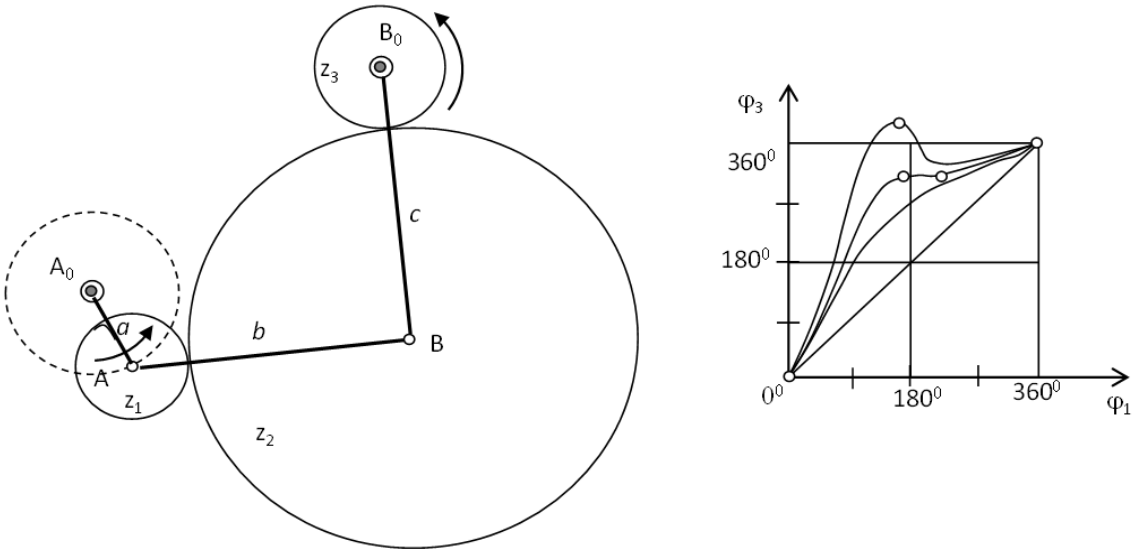


(a) (b)

Fig. 1: The mechanism with geared wheel

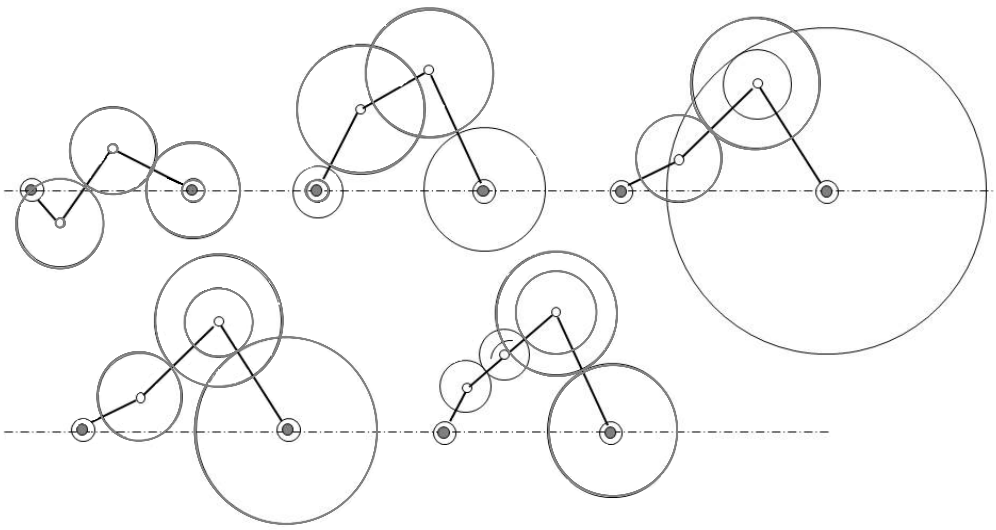
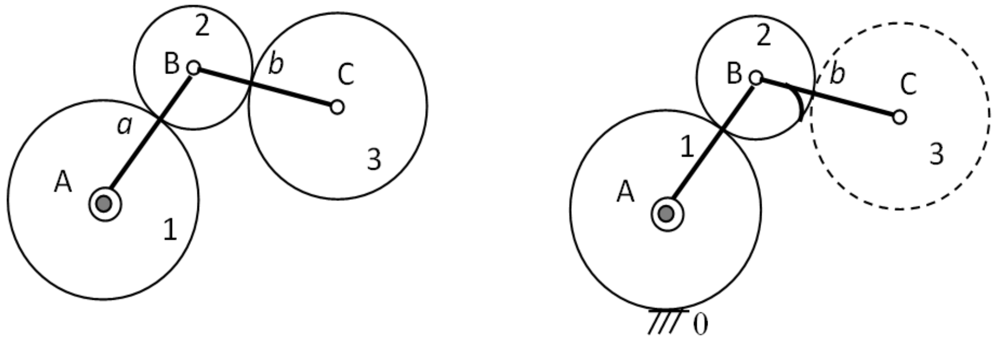


Fig. 2: Schematic of rods and gears constructed on the basis of the four-tiered bar mechanism



(a) (b)

Fig. 3: An example of multi mobile mechanism with bars and gears

Results

The movement of the point B (Fig. 3a) can be controlled by conditioning the displacement of point B, for example (Fig. 4) on the circular arc with the BD radius and the fixed D center.

The resulting mechanism has two mobilities; in its movement the driven wheel 4 depends on the angular velocity of one of the toothed wheels of the series chain wheel and the angular velocity of one of the bars of the articulated quadrilateral mechanism.

This quadrilateral mechanism can be accepted as a basic mechanism. This case, starting from its kinematic relationship, can be extended to different particular cases.

It is a question of determining the angular velocity of one of the sprocket wheels, for example, z_3, depending on ω_1 and ω_a date.

The mechanism with bars and gears represented in Fig. 4 can be considered as two differential mechanisms with known movements of the known bars a and c at which the angular speeds of the wheels 2 and 3 are in a determined ratio.

If the link between the wheels 2 and 3 is assumed to be interrupted, then the following can be written:

$$i_{12}^{a} = \frac{\omega_1 - \omega_a}{\omega_2 - \omega_a}; i_{34}^{c} = \frac{\omega_3 - \omega_c}{\omega_4 - \omega_c} \quad (1)$$

where the transmission ratios i_{12}^{a} and i_{34}^{c} are calculated in the case of the fixed axle outer gear:

$$i_{12}^{a} = -\frac{z_2}{z_1}; i_{34}^{c} = -\frac{z_4}{z_{3'}} \quad (2)$$

From formulas (1), the angular speeds of wheels 2 and 4 are explained:

$$\omega_2 = \omega_1 \cdot i_{21}^{a} + \omega_a \left(1 - i_{21}^{a}\right) \quad (3)$$

$$\omega_4 = \omega_3 \cdot i_{43}^{c} + \omega_c \left(1 - i_{43}^{c}\right) \quad (4)$$

The transmission ratio of gear units 2, 3 is written in relation to b:

$$i_{23}^{b} = \frac{\omega_2 - \omega_b}{\omega_3 - \omega_b} = -\frac{z_3}{z_2} \quad (5)$$

From formula (5) it is deduced:

$$\omega_3 = \omega_2 \cdot i_{32}^{b} + \omega_b \left(1 - i_{32}^{b}\right) \quad (6)$$

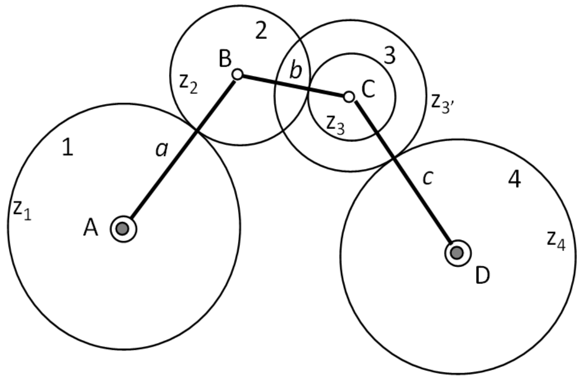


Fig. 4: Two differential mechanisms with known movements

By observing formulas (3) and (6) of formula (4), the angular velocity of the wheel 4 is obtained according to the angular speed of the wheel 1 and the three bars a, b and c:

$$\omega_4 = \omega_1 \cdot i_{21}^{a} \cdot i_{32}^{b} \cdot i_{43}^{c} + \omega_a \cdot \left(1 - i_{21}^{a}\right) \cdot i_{32}^{b} \cdot i_{43}^{c} + \omega_b \cdot \left(1 - i_{32}^{b}\right) \cdot i_{43}^{c} + \omega_c \left(1 - i_{43}^{c}\right) \quad (7)$$

In this Equation 7 ω_b and ω_c are functions of ω_a and can be determined as transmission functions between the bars of the quadrilateral mechanism:

$$\omega_b = \omega_a \cdot i_{ba}; \omega_c = \omega_a \cdot i_{ca} \quad (8)$$

This is why ω_4 it is a function of two independent variables ω_4 and ω_a.

For all the gear and gear mechanism schemes of Fig. 2, in which the wheel 2 is locked with the arm a, the required condition is $\omega_2 = \omega_a$.

In these cases it results $\omega_1 = \omega_a$ from Equation 3, which means that the z_1 wheel is locked with the crank a and formula (7) becomes:

$$\omega_4 = \omega_a \cdot i_{32}^{b} \cdot i_{43}^{c} + \omega_b \cdot \left(1 - i_{32}^{b}\right) \cdot i_{43}^{c} + \omega_c \left(1 - i_{43}^{c}\right) \quad (9)$$

If the wheels 2 and 3 are blocked on b, then $\omega_2 = \omega_3 = \omega_a$, so that from Equation 3 and 4 the relations are deduced:

$$\omega_1 = \omega_b \cdot i_{12}^{a} + \omega_a \cdot \left(1 - i_{12}^{a}\right) \quad (10)$$

$$\omega_4 = \omega_b \cdot i_{43}^{c} + \omega_c \cdot \left(1 - i_{43}^{c}\right) \quad (11)$$

Formula (10) can be used to calculate the angular velocity of the driven element (Dudita, 1989) of the Watt engine mechanism (Fig. 5), in which the wheels are missing z_3 and z_4 and $\omega_c = 0$.

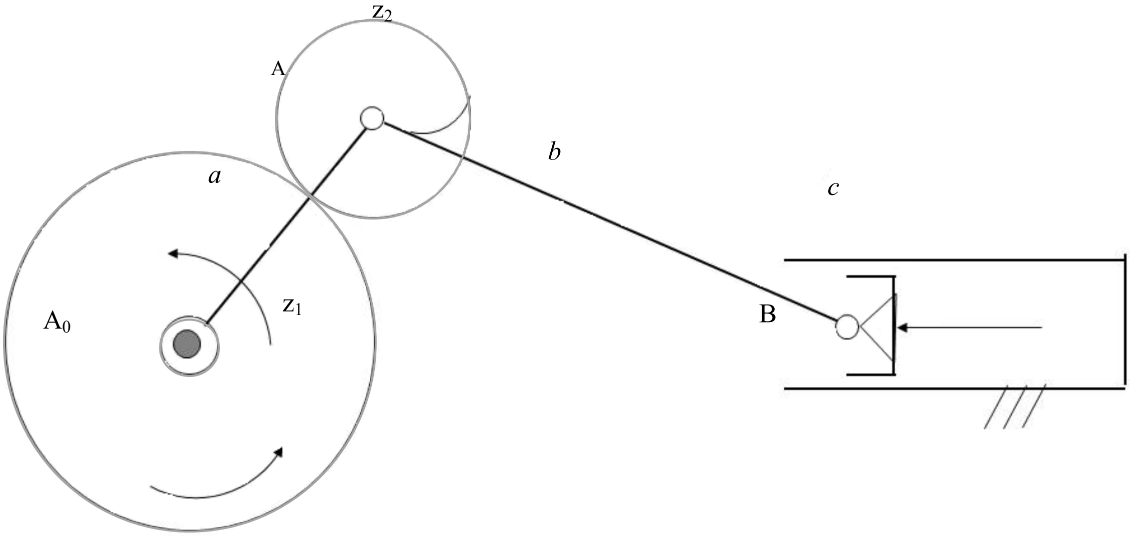


Fig. 5: Watt engine mechanism

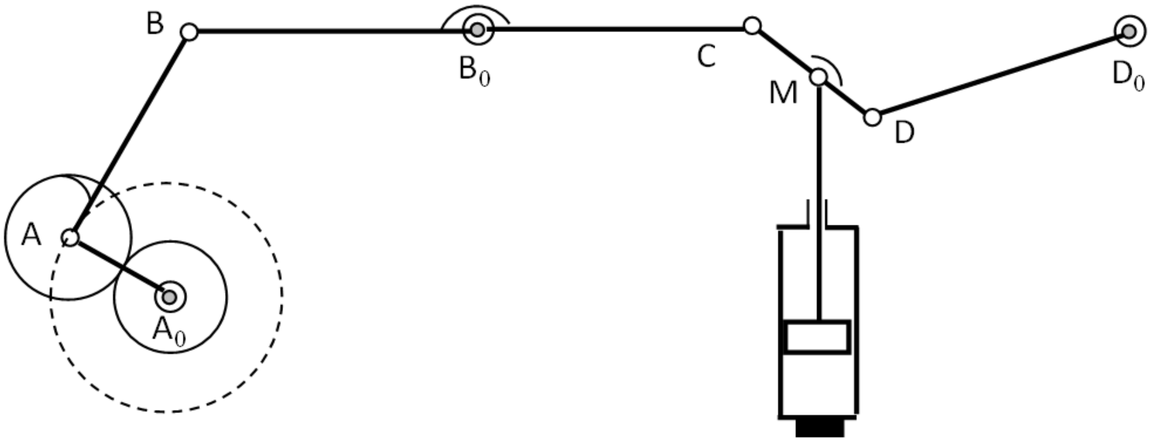


Fig. 6: Watt imagined a new mechanism, combining the crankshaft mechanism with a planetary gear with two gears

It is worth mentioning that J. Watt used such a steam machine scheme that he patented in 1784 (Dudita, 1989).

Following the transformation of the oscillating rotation movement in continuous rotation, J. Watt imagined a new mechanism, combining the crankshaft mechanism with a planetary gear with two gears (Fig. 6).

Note that the translational movement of the piston is approximately maintained by the point M on the bar of a rocker-rocker articulated, which had already been invented by J. Watt.

The translational movement of the piston in the vertical cylinder (Fig. 6) first turns into oscillating rotation of the BB_0C, after which the balancing motion is transformed into a continuous rotation motion by means of a planetary gear with a central wheel and a satellite wheel Solidarity with white AB.

The Englishman E. Cartwright invented in 1800 (Dudita, 1989; Kojevnikov, 1969) a guiding mechanism with articulated bars and two symmetrically arranged toothed wheels (Fig. 7a) for the purpose of transforming the reciprocating movement of the piston (driven by steam) in motion Rotation of the steering wheel.

The piston rod 1 is articulated with the bar 2 at the point E, which is located on the mediator of the CD segment. The trajectories of the points C and D are rectilinear parallel to the piston rod 1. The A_0A and B_0B manikins are mounted integrally on each respective wheel gear 5 and 6 in a symmetrical position relative to the vertical point E, which provides for equal rotation angles.

From the analysis of the equivalent kinematic scheme (Fig. 7b), which specifies the leading element 1, the symmetry is even more emphasized.

The topological structure of this mechanism identifies a passive (zero mobility) cinematic chain whose hexagonal configuration is (Antonescu, 2003).

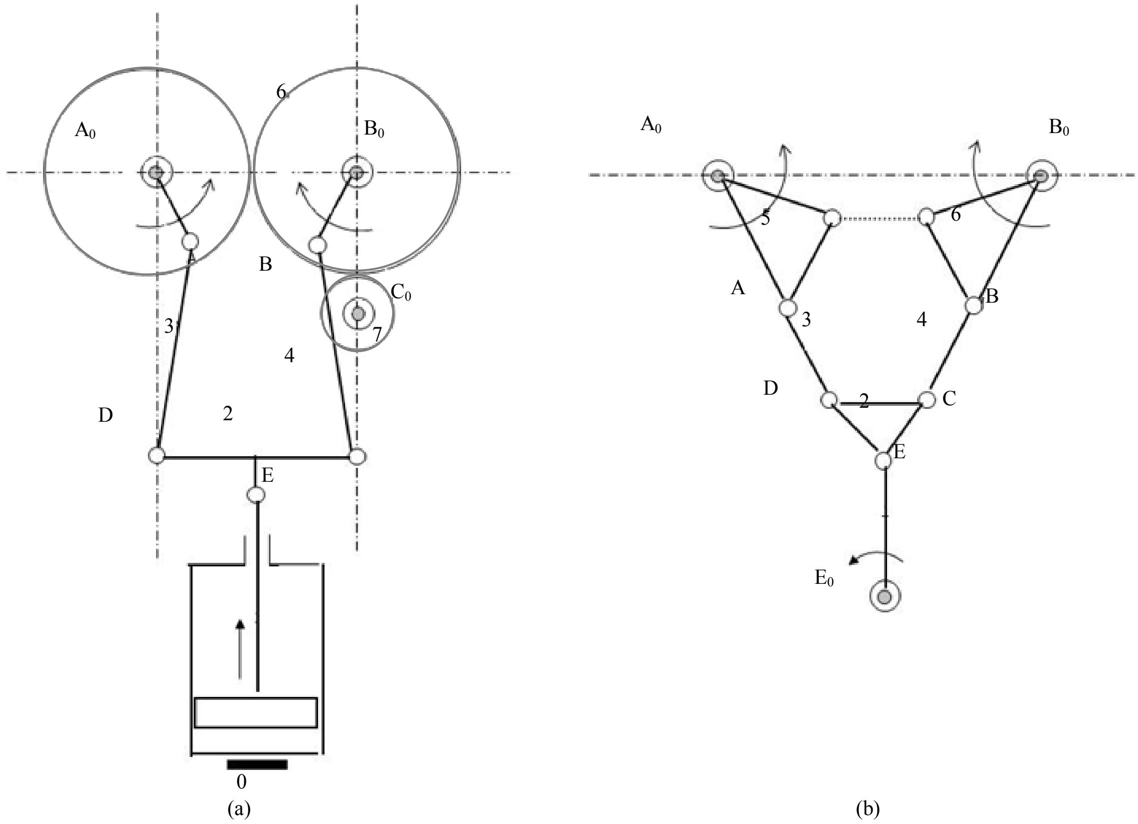


Fig. 7: A guiding mechanism with articulated bars and two symmetrically arranged toothed wheels

Discussion

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The modern industry, the practice of designing and building machinery is increasingly based on the results of scientific and applied research. Each industrial achievement has backed theoretical and experimental computer-assisted research, which solves increasingly complex problems with advanced computing programs using an increasingly specialized software.

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Conclusion

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Author's Contributions

All the authors contributed equally to prepare, develop and carry out this manuscript.

Ethics

This article is original. Authors declare that are not ethical issues that may arise after the publication of this manuscript.

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