UNIVERSITATEA BABEȘ-BOLYAI
BABEȘ-BOLYAI TUDOMÁNYEGYETEM
BABEȘ-BOLYAI UNIVERSITÄT
BABEȘ-BOLYAI UNIVERSITY
TRADITIO ET EXCELLENTIA

Doctoral School of Engineering
Faculty of Engineering

Traian Vuia Square no. 1-4
Reșița, RO-320085
Phone: 0730 583 011
contact.eng@ubbcluj.ro

Contributions to the research of inertial mechanisms

Abstract of the doctoral thesis

Scientific Supervisor
Conf. univ.dr.ing. habil. Zoltan-Iosif KORKA

Doctorand
Ing. Stelică TIMOFTE

Reșița,

2025

CONTAINED

No.	Title	Page
	Foreword	1
	Contained	2
	List of notations	4
	List of figures	6
	List of tables	9
	Introduction	10
1.	**Current state of inertial mechanism research**	12
1.1	Brief history of inertial mechanisms	12
1.2	Patented inertial mechanisms	22
	1.2.1 Patent US20190331096A1 "Directional Motive Force Generating Device"	23
	1.2.2 Patent US5388470A "Centrifugal Force Actuator"	28
	1.2.3 Patent EP001114930A1 "Traction Generator Device and Moving Body"	30
	1.2.4 Patent US20050139022A1 "Propulsion apparatus using centrifugal force"	32
	1.2.5 Patent US20060005644A1 "Centrifugal generator of a tensile force for aviation and space aircraft"	34
	1.2.6 Patent US20080060460A1 "Propulsion device using the conversion of rotational motion into a unidirectional linear force"	37
	1.2.7 Patent WO2013087991A1 "Propulsion Force Delivery Device"	40
	1.2.8 Patent WO2008153397A1 "Method and device for generating a force vector"	44
	1.2.9 Patent WO200105555592A1 "Centrifugal propulsion system"	48
1.3	Research from the Doctoral School of Engineering of UBB	49
1.4	Conclusions	54
2.	**Contributions to the theoretical and experimental study of an inertial linear propulsion mechanism**	55
2.1	Theoretical considerations	55
2.2	Proposed inertial propulsion mechanism	56
2.3	Kinematic and dynamic analysis of the inertial propulsion mechanism	57
2.4	Practical implementation of the mechanism	72
2.5	Conclusions	79
3.	**Contributions to the development of a new inertial propulsion system using eccentric masses**	80
3.1	General considerations	80

No.	Title	Page
3.2	Description of the inertial propulsion system	82
3.3	Analytical research of inertial propulsion system	83
3.4	Vehicle Motion Simulation	86
3.5	Results and discussions	87
	3.5.1 Vehicle speed simulation	87
	3.5.2 Simulation of energy consumption	88
3.6	Experimental Proof of Concept	89
3.7	Conclusions	92
4.	**Contributions to the development of an innovative inertial mechanism to reduce reaction time**	94
4.1	General considerations	94
4.2	Mechanism design and operating principle	95
4.3	Analytical calculation of system dynamics	97
4.4	Numerical example and discussions	107
	4.4.1 Influence of drive speed	108
	4.4.2 Influence of the specific mass of the weights attached to the chain	109
	4.4.3 Influence of the radius of the small chain wheel	110
4.5	Conclusions	111
5.	**Final conclusions and personal contributions. Future research directions. Dissemination of results**	113
5.1	Concluding remarks	113
5.2	Personal contributions	116
5.3	Future research directions	118
5.4	Dissemination of results	119
	Bibliography	120

INTRODUCTION

Inertial mechanisms represent a promising area of technological and engineering research, with diverse applications in innovative propulsion systems. The field has attracted the attention of the scientific community due to its potential to provide efficient and reliable alternative solutions for the propulsion of vehicles and appliances in situations where traditional methods become insufficient, such as moving on slippery surfaces, confined spaces or environments where traditional traction is limited [1],[2].

There are many approaches to inertial mechanisms in the literature [3-6], from space propulsion and autonomous vehicles to specific industrial applications. Systems based on inertial mechanisms offer the advantage of generating propulsion without direct interaction with the external environment, which makes them extremely attractive for special operating conditions, such as space exploration, advanced robotics and underwater environments.

The present thesis continues the research previously initiated in the doctoral school of engineering of Babeș-Bolyai University and aims to make significant contributions to the study of inertial mechanisms, exploring the current technological opportunities in the field of advanced numerical simulation, additive manufacturing and the development of integrated mechatronic systems. Among the opportunities identified are the development of mechanisms with improved energy efficiency, reducing the negative impact of reaction moments, miniaturization of components for applications in microrobotics and the use of advanced materials to optimize the mass and strength of structures [7-10].

The opportunity of the research carried out during the doctoral studies resulted from the desire to develop new propulsion systems, as an alternative to the existing ones and to design an original system for eliminating the reaction moment, with multiple applications.

The objectives of this thesis were:

O1: Investigation of the most significant inertial mechanisms patented and developed to date;

O2: Conception and practical materialization of inertial mechanisms;

O3: Analytical study of the kinematics and dynamics of these mechanisms;

O4: Study of the influence of the main geometric elements of mechanisms on the dynamics of systems;

O5: Numerical simulation of the functioning of the mechanisms;

O6: Comparison of analytical calculations with simulation results;

O7: Comparison of the results of experimental measurements with those of simulations.

The paper is structured in five chapters that deal with distinct theoretical and experimental aspects, each developing a specific and complementary theme in the general framework of the research.

Chapter 1 "*The current state of inertial mechanism research*" analyzes patents and recent research relevant to inertial mechanisms, establishing the scientific and technological context of the work and revealing current trends in the literature.

Chapter 2 "*Contributions to the theoretical and experimental study of an inertial mechanism of linear propulsion*" describes the functional principle of the proposed device, carrying out detailed kinematic and dynamic analysis, practical realization of the prototype.

Chapter 3 "*Contributions to the development of a new inertial propulsion system using eccentric masses*" explores the design, theoretical analysis and numerical simulations of an eccentric mass-based propulsion system, aiming to optimize performance in terms of speed and energy consumption

Chapter 4 "*Contributions to the development of an innovative inertial mechanism for reducing the reaction moment*", introduces a constructive solution to minimize the undesirable effects generated by the reaction moment. The content includes detailed analytical calculations and numerical examples that validate the proposed approach.

Chapter 5 "*Final conclusions and personal contributions. Future research directions. Dissemination of results*" summarizes the results obtained, highlights the author's original contributions and proposes clear perspectives for future research. At the same time, details on the dissemination of research results in academic journals and national and international conferences are presented.

1. THE CURRENT STATE OF INERTIAL MECHANISM RESEARCH

The motivation of researchers in the field of inertial mechanisms is multiple. Some of the researchers have found a supposed way to break the laws of physics so that they can perform action without reaction and thus increase the efficiency of the machines. Others have found an alternative way to move heavy objects by vibration without actual lifting, thus saving energy costs Gyroscopes have also been used to take energy from waves.

In terms of space applications, the trend of researchers replacing fuel-consuming rockets for interstellar space travel is also a particularly important topic for the future of humanity. Some of the alternatives were reported in [11],[12]. And because the supply of new inventive ideas was abundant and urgent (more than three applications a day), in 2006 NASA decided to publish a report to discourage new inventors [13].

However, although the subject of inertial mechanisms does not seem to offer a practical means of spatial propulsion in itself, it is interesting to note the course that the human mind has followed so far and dreamed of a better future. This chapter attempts to provide a comprehensive approach for future research on this topic.

The main conclusions that emerged from this chapter are:

- Inertial mechanisms are a topic of technological and engineering research, with diverse applications in innovative propulsion systems.
- The field has attracted the attention of the scientific community due to its potential to provide alternative and reliable solutions for the propulsion of vehicles and appliances in situations where traditional methods become inefficient.
- Although, in the last decade, more than 100 inertial mechanisms have been patented, the vast majority of them have not been practically implemented, remaining only at the patent or theoretical research stage.
- Systems based on inertial mechanisms offer the advantage of generating propulsion without direct interaction with the external environment, which makes them extremely attractive for special operating conditions, such as moving on slippery surfaces, space exploration, advanced robotics and underwater environments, where traditional traction is limited.
- The research on inertial devices carried out at the Babeș-Bolyai University has opened new directions of investigation in the field of alternative propulsion. Through an interdisciplinary approach, combining applied mechanics, robotic engineering and numerical modeling, these

studies have made significant contributions to the understanding and optimization of these systems.

- Although inertial mechanisms have so far failed to impose themselves as practical means of propulsion, due to their dynamic characteristic and low efficiency, it is interesting to note the course that the human mind has followed so far and dreamed of a better future.
- In the future, the development of new generations of inertial devices that integrate advanced materials and intelligent control algorithms to improve their efficiency and scalability is anticipated. Also, international collaborations and extensive experimental testing will help validate these technologies in real applications.

2. CONTRIBUTIONS TO THE THEORETICAL AND EXPERIMENTAL STUDY OF AN INERTIAL LINEAR PROPULSION MECHANISM

Linear trajectory inertial mechanisms are part of a new field of research and, therefore, in recent decades, they have received special attention from engineers and researchers. These mechanisms are multi-body systems, with masses in eccentric motion, being usually constructed, symmetrically, to cancel unwanted forces in the direction perpendicular to the desired direction of travel. The displacement is ensured by a propulsive force generated as a result of the reaction to centrifugal forces acting on a number of masses that rotate on a complex trajectory.

As presented in the previous chapter, since the last decades of the last century, numerous devices have been patented that use centrifugal force to generate linear propulsion. Unfortunately, whether we are talking about the initial or the most recent attempts, only a few of these systems have passed the patenting phase and have been involved in practical applications. This chapter presents an inertial linear propulsion mechanism, developed by the author of the thesis, which uses the kinetic energy of several masses, placed at the articulation points of the links of a transmission chain, to generate linear motion.

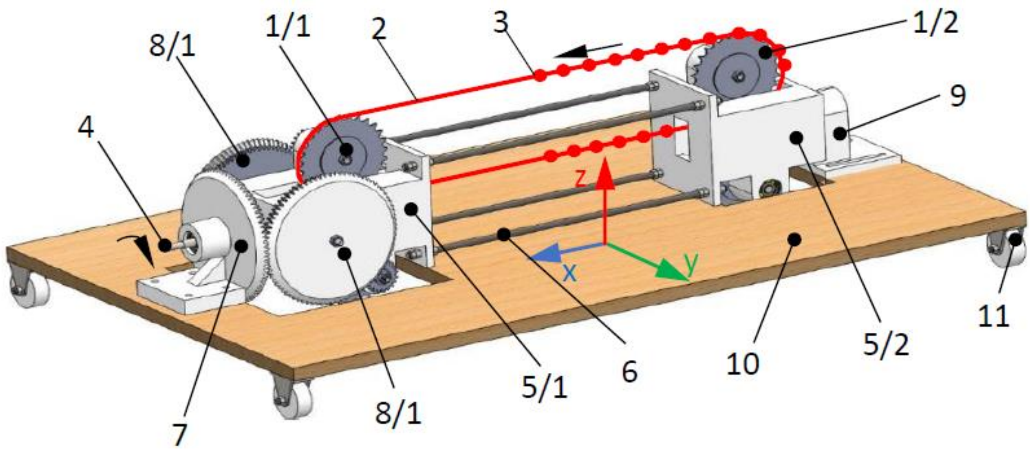

Figure 2.1. Overview of the propulsion mechanism

The masses placed equidistantly along the semi length of the chain execute a complex movement, consisting of the specific displacement of the chain elements and a rotation around an axis, which is parallel to the line that joins the centers of the chain wheels. After deducing the equations of the geometric coordinates of the masses, the total propulsion force was calculated. The results obtained support the ability of the inertial propulsion system to generate propulsive force and linear motion.

At the end of this chapter, the conclusions can be summarized as follows:

- The chapter proposes a new inertial mechanism of linear propulsion, developed by the author of the thesis, which uses the kinetic energy of several masses, placed at the articulation points of the links of a transmission chain, to generate linear motion.
- The masses placed equidistantly along the semi length of the chain execute a complex movement, consisting of the specific displacement of the chain elements and a rotation around an axis, which is parallel to the line that joins the centers of the chain wheels.
- After deducing the analytical equations of the geometric coordinates of the masses, the total propulsion force was calculated, the results obtained supporting the possibility that the mechanism has the ability to generate propulsion force and linear motion.
- Starting with the assembly modeling in the SOLIDWORKS work environment, most of the components were manufactured using 3D printing.
- Repeated attempts to put the mechanism into operation proved to be, each time, failures, because the recommendation in the Machinery Parts course was ignored, according to which "*chain transmissions work correctly if the chain is located in the vertical plane*".

3. CONTRIBUTIONS TO THE DEVELOPMENT OF A NEW INERTIAL PROPULSION SYSTEM USING ECCENTRIC MASSES

In the process of researching the theme of this chapter, I found that, even though the topic is quite old, dating back to antiquity, when ancient Greek athletes used dumbbells to prolong their long jumps. [140], the theme arouses interest even today [128] [61] [135] [141].

The concept of counter-rotating masses could be used to propel vehicles on land, in water and in space. However, from a strictly mechanical point of view, there is the following controversy: since inertial forces are internal forces, the rotation of masses does not produce an external force (thrust) that accelerates the center of mass of the system. However, numerous scientists [135], [62], [69], have made efforts to address this controversial issue, and even NASA has conducted a six-year research program in this field [13], but providing only qualitative information.

One of the most studied inertial propulsion systems is the Dean thruster, also known as the Dean apparatus [25], [47], [27]. It was patented in 1959 [142] and uses two counter-rotating eccentric masses mounted on a stand, which is guided on vertical rails. Traction springs are used to secure the bracket to the housing.

Many of the patented inertial drives have not had a practical materialization. One such example is the propulsion system proposed by Boden [120]. It produces a unidirectional thrust by converting the energy of two identical assemblies of weights rotating in opposite directions. The peculiarity of the system lies in the rotating elements, which move with variable turning radii around a fixed point to achieve an unbalanced centrifugal force. As a result, a propulsive force is generated after a certain direction.

The propulsion apparatus suggested by Cuff [143] includes a device that allows the variation of the radius of rotation of several masses and the correct adaptation of the direction of the resulting unbalanced force produced by these rotating weights. The device includes two fixed circular cams, eccentrically arranged. The cam fillers are joined with rods that are successively connected to the rotating masses. The direction of the resulting unbalanced force can be changed by rotating the jointly fixed cams accordingly.

Similarly, Dobos [144] proposes an apparatus comprising a platform mounted perpendicular to a shaft. The shaft also supports a disc on which several tanks containing a liquid are placed around the edge of the circumference. A hollow piston with a piston rod extending outwards from the tank is positioned in each tank. An adjustable movable cam with a cam path positioned eccentrically to the axis of the shaft assembly is mounted on the shaft assembly. To enter and exit contact with the cam path, the end sections of the piston rod are placed opposite the cam route. To advance the cams to a predetermined position for the pistons to move in the tanks as the disc rotates around the cam, a load head exerts a downward force against a bent flexible shaft that engages in one shoulder on the cam's maximum radial sector. The relative displacement of the liquid in the tanks by the movement of the pistons in response to the contact of the piston rods with the cam path creates an unbalanced centrifugal force to move the platform in a pre-selected linear direction.

Later, Deschamplain [145] patented a propulsion device that uses fluids to convert rotational motion into linear motion. For this purpose, the system includes a centrifuge with a cell that is partially filled with water. While the centrifuge is driven by a motor, the centrifugal force moves the fluid outwards. The assembly also contains an object that is positioned at its outer end in water and its inner end in air. A road that rotates at the same speed as the centrifuge is placed parallel to the axis of the centrifuge, at a certain distance, being connected to the object by a coupling. The centrifugal forces generated by the synchronous rotation of the centrifuge and the roads are used to generate linear motion.

In the same year, Murray [146] obtained a patent for a mechanical force generator, which converts the cinematic energy of centrifugal force into propulsive force, using a cage assembly that rotates around its longitudinal axis. The cage is rotated by secondary shafts that rotate sets of eccentrics to generate a net force in a transverse direction from the axis of rotation of the cage assembly. Two pairs of eccentrics rotate in such a way that, for every 90° rotation of the load-bearing cage, the pairs of eccentrics have their centers of mass placed rather between an equilibrium and an unbalanced state, but, at each 90° angle of rotation, a pair of eccentrics always produces a force stroke.

More recently, Loukanov [147] presented a concept of a unidirectional mobile robot, by using two eccentric masses that rotate synchronously. Motion is achieved by both inertial and frictional forces. To avoid resonance, the mobile platform includes a system of springs and dampers. In addition, unidirectional roller bearings mounted in the wheel hubs ensure unidirectional movement of the vehicle, suppressing unwanted backward movement. Based on this concept, the author built a wheeled vehicle that he tested on surfaces with different friction and supporting different weights.

Following the documentation, we designed a new propulsion system of a mobile platform, which would use as many of the components manufactured for the chain drive as possible. The new system uses the inertial force generated by two eccentric masses, which rotate in opposite directions. Despite the similar concepts that have been presented previously, the inertial propulsion system (SPI) proposed by me ensures a movement with an oscillating but permanently positive speed. In addition, the speed of movement can be favorably determined by a proper correlation of the masses of eccentric bodies with the mass of the entire platform. In addition, the initial position of eccentric bodies determines the direction of travel. Based on this approach, we redesigned and built the new wheeled vehicle, also using 3D printing techniques. The validation of the concept and the verification of the analytically obtained kinematic parameters were then carried out by 3D modeling and motion simulation, carried out with the help of the SolidWorks program. Finally, the system was experimentally tested.

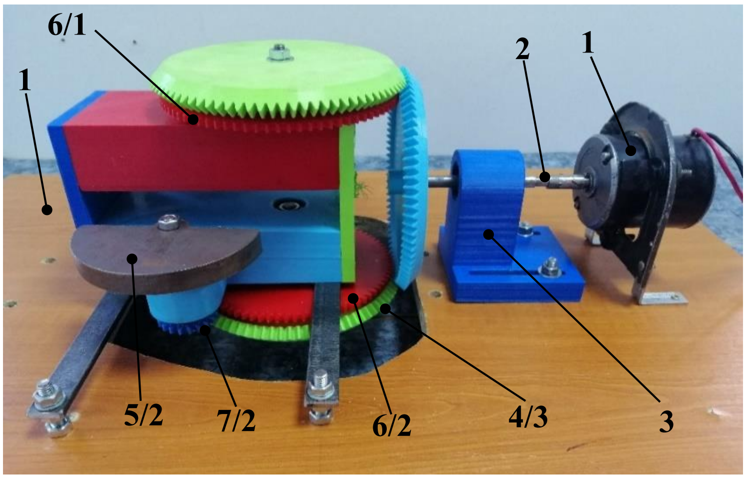

Figure 3.1. Inertial propulsion system with counter-rotating eccentrics

This chapter proposes an original concept of propulsion of a mobile platform. The system uses the inertial force generated by two eccentric masses, which rotate in opposite directions. The verification of the kinematic parameters obtained by analytical means and the validation of the concept were performed in SolidWorks by motion simulation. Also, to demonstrate the system's ability to produce linear motion, a prototype was built and experimental tests were conducted.

The main conclusions of the chapter are as follows:

- Operating the system over five different distances, it was observed that the differences between the measured average speed of the SPI and the simulated results are less than 10%.
- The speed of the platform can be increased by increasing the speed of the engine masses.
- By doubling the speed of the driving masses (from 500 to 1000 rpm), the average speed of the platform increases by 3.99 times. This result confirmed the dependence between these two parameters deduced by analytical means.
- By increasing each engine mass by 2.5 times (from 0.18 to 0.45 kg), the speed of the platform increases by 2.28 times (from 93.72 to 214.13 mm/s). The nonlinear dependence between these two parameters has been explained by the analytical relationships previously deduced.
- The developed system is functional and capable of generating unidirectional linear motion, making it particularly suitable for driving propellerless boats or submarines.
- The proposed system is the only alternative for driving vehicles on very slippery surfaces (mud or ice), where no tire provides the necessary grip to move in such conditions.

4. CONTRIBUTIONS TO THE DEVELOPMENT OF AN INNOVATIVE INERTIAL MECHANISM TO REDUCE REACTION TIME

As is known, the torque produced by a rotary motor generates an opposite and equal reaction torque in the car's housing, which must be transmitted to the base. In many applications, especially when the reaction moment has high values, it is necessary to apply some constructive solutions, which in some cases are difficult to implement. In this context, the need to reduce the reaction time from drive motors is a challenging topic that has not been completely exhausted. This chapter presents an original concept of a device that uses the centrifugal force generated by some weights placed equidistantly on a chain drive to reduce the reaction torque of the motor used to drive a rotary tool. The proposed system is capable of producing additional torque that can be added at the time of drive. Thanks to this, by using this system, the power of the drive motor can be reduced, with the consequence of reducing the reaction moment that must be absorbed by the base.

According to Newton's third law, there is an equal and opposite reaction to every action. This principle is most commonly applied to linear forces, but it is also true for angular or rotary systems [148]. In this case, the torque, or torque, is the angular equivalent of force. A torque can cause a mass to accelerate angularly, in the same way that a linear force can accelerate a linear mass. Thus, a momentary reaction is the equal and opposite response to a torsional moment. Managing this reaction moment is fundamental in many technical applications, such as helicopter blade transmissions, motorcycle rear wheels, rotary tools that operate in variable speed conditions, manually supported tools, and so on.

A helicopter performs the lift from the ground through the effect created by the blades, which deflect the air downwards. The upward force acting on the helicopter is equal to and opposite to this downward force acting on the air. There is also an equal and opposite reaction caused by the rotating blades. The rest of the helicopter tends to rotate in the opposite direction, as the motor rotates the blades in only one direction. Therefore, a rotor at the rear of the helicopter, made up of smaller blades, drives the air in a horizontal direction, to counteract the reaction moment produced by the engine trying to rotate the main blades. Thus, the stable flight of the helicopter can be achieved [149-152].

The problem of canceling the reaction moment was solved in a different way by the Boeing CH-47 Chinook helicopters [153]. They use two sets of vanes, called tandem rotors, which rotate in opposite directions, the two reaction moments canceling each other out. This principle is also involved in other helicopters that are used to lift heavy loads [154-157] directions.

Reaction time is also an important issue in the case of land vehicles [158,159]. For example, to start a motorcycle from a standstill, a moment must be applied to the rear wheel. If, when starting from a standstill, it accelerates suddenly, the reaction moment produced is enough to overcome the weight of the motorcycle, causing the front of the motorcycle to rise. This can also happen while driving, when the throttle lever is suddenly pressed.

In the case of hand-held tools, such as hand drills or screw tighteners, the reaction moment that occurs at start-up must be counteracted by the operator's hand. At high reaction moment values, it can cause serious injury to the operator's hand. [160,161].

In this chapter, an original concept is proposed that involves a special device for reducing the reaction moment of the motor used to drive a rotary tool. Similar devices have captivated the enthusiasm of many academic researchers, but also of some aerospace engineers, who have made a significant number of patents [162-190].

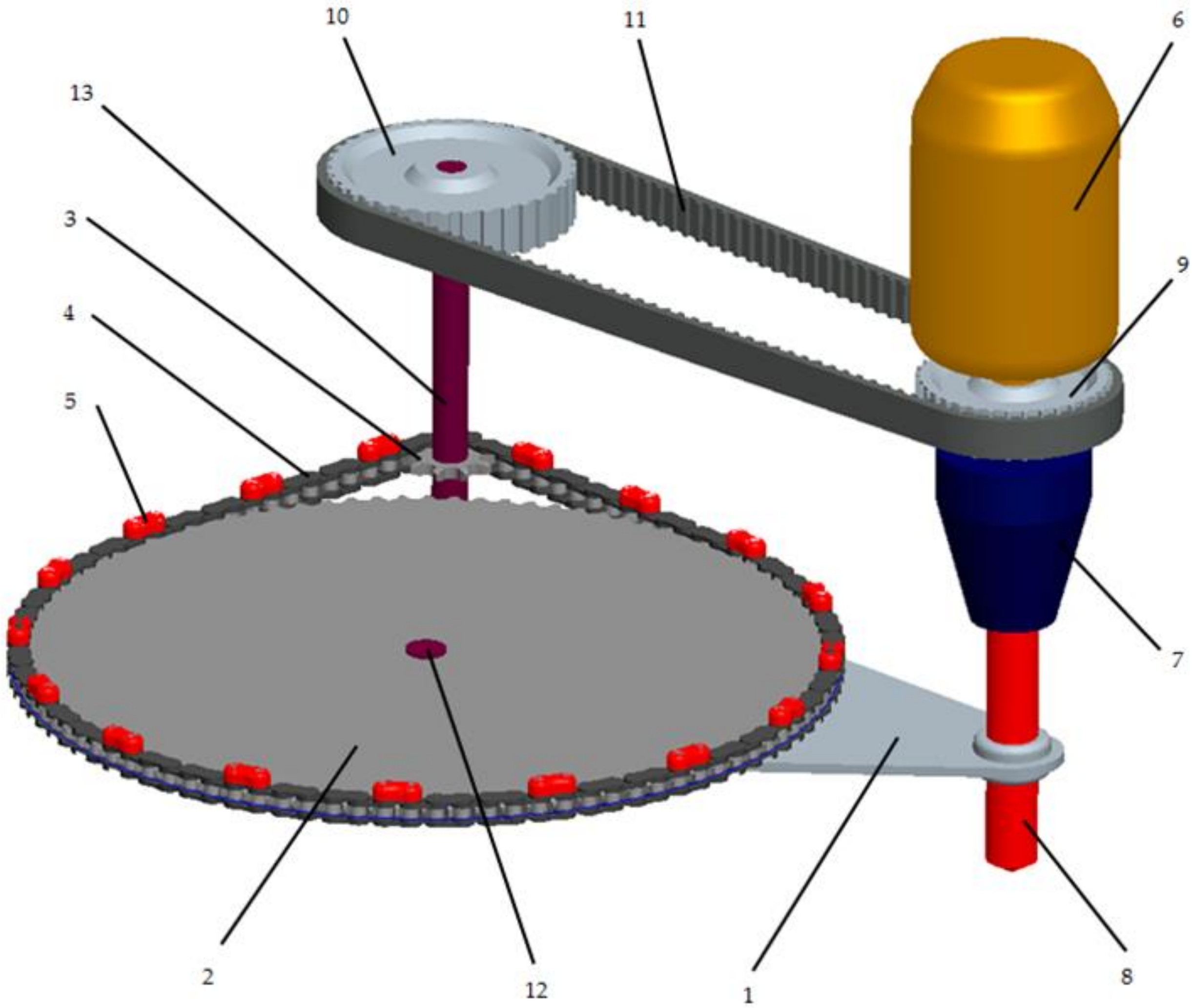

Figure 4.1. Construction of the device to reduce the reaction moment.

The device developed in this chapter is capable of producing, by means of centrifugal forces generated by weights placed on a chain drive, an additional moment for driving a rotary tool. In addition, the chapter details the dynamics of the system and exemplifies its benefits for a concrete case. In addition, several numerical examples were presented showing the influence of different parameters (drive speed, specific mass of the weights attached to the chain and the radius of the small chain wheel) on the additional moment produced by the system.

The proposed device could be incorporated into hand-supported tools, such as screw tighteners used in extreme working conditions (when assembling wind turbine blades, for example) or in motorized drill bits for digging holes. In these applications, the implementation of the concept would help reduce the risk of injury, as the system is able to reduce reaction time and minimize the possibility of the operator suffering musculoskeletal disorders in the upper limbs.

The main conclusions that can be drawn from this chapter are the following:

- The extra moment generated by the device is constant, if the polygonal effect of the chain is neglected.
- The extra moment generated by the device is independent of the drive power, with the system showing higher efficiency as the drive power decreases. However, there is a lower power limitation, related to the need to overcome the inertia of the system during the start-up process.
- The additional moment generated by the system can be increased by:
  # increasing the mass of weights added to the chain;
  # increasing the radii of the chain wheels;
  # by increasing the speed of the drive.
- If, during operation, there is a sudden increase in the resistive moment at the work tool, the reaction moment that occurs at the motor is attenuated by this device, making the handling of the entire system easier.

The main disadvantages and limitations of the proposed system consist of:

- relatively large size;
- the need to take special protective measures;
- The system only works correctly in one direction of rotation.

The relatively large size of the device imposes the need to take special protective measures, as the holder (1) and the other associated elements rotate together with the tool (8). In addition, the system only works correctly in one direction of rotation. In the event of a change in the direction of rotation, centrifugal forces acting on the masses attached to the chain reduce the drive moment of the tool.

Possible future research directions are the following:

- Optimizing the design so as to minimize the size of the device;
- Making a prototype of the device and conducting experimental tests;
- Study of how the additionally generated moment is influenced, if the transmission ratio of the synchronous belt is different from 1.

5. FINAL CONCLUSIONS AND PERSONAL CONTRIBUTIONS. FUTURE RESEARCH DIRECTIONS. DISSEMINATION OF RESULTS

This doctoral thesis aims to contribute to the research and development of innovative inertial mechanisms. Starting from this main objective, the research started from the detailed study of the literature, similar existing systems and a significant number of patents.

Within this thesis, significant contributions have been made, which consist of:

- Conducting an extensive and detailed analysis of the existing literature in the field of inertial mechanisms, with clear identification of research gaps and opportunities;
- Development of two inertial propulsion mechanisms and a device to reduce the reaction moment of the motor used to drive a rotary tool;
- Detailed design and precise 3D modeling, adapted to the specific requirements of the proposed applications;
- In-depth analytical analysis of kinematics and dynamics of mechanisms, with the formulation of relevant mathematical equations;
- Carrying out extensive numerical simulations;
- Construction and testing of two prototypes, of which only one proved to be functional, confirming the practical feasibility and high efficiency of the proposed technical solution;
- Detailed evaluation of the influence of the main geometric and dynamic parameters on the performance of the proposed mechanisms;
- Validation of the results through multiple experimental tests with various scenarios.

Table 5.1 summarizes the achievements and contributions obtained within the thesis, compared to the objectives proposed to be achieved:

Table 5.1 Synthesis of the achievements and contributions obtained within the thesis, compared to the objectives

Objectives of the thesis	Achievements obtained within the thesis	Personal contributions
O1: Investigation of the most significant inertial mechanisms patented to date	**R1**: Conducting an extensive and systematic study of existing literature and patents, critical analysis of about 200 bibliographic	**C1.1**: Critical and detailed analysis of these types of mechanisms, identifying the main advantages and limitations

Objectives of the thesis	Achievements obtained within the thesis	Personal contributions
	references and patents, to identify key features and limitations of existing devices	**C1.2**: Reviewing and examining the previous research undertaken in the Doctoral School of Engineering of Babeș-Bolyai University on the topic of inertial mechanisms
O2: Conception and practical materialization of inertial mechanisms	**R2**: Development of two inertial propulsion mechanisms and a device to reduce the reaction moment of the motor used to drive a rotary tool	**C2.1**: Designing devices and making 3D models using specialized software (SolidWorks) **C2.2** Active and direct participation in the construction of two prototypes
O3: Analytical study of the kinematics and dynamics of these mechanisms	**R3**: Deduction of analytical equations regarding kinematics and dynamics of mechanisms	**C3:** Realization and mathematical validation of a complete set of analytical equations that accurately describe the kinematic and dynamic behavior of the proposed mechanisms.
O4: Study of the influence of the main geometric elements of mechanisms on system dynamics	**R4:** Detailed analysis and quantification of the influence of geometric parameters on the performance of mechanisms, expressed through explicit analytical calculations	**C4:** Development of detailed mathematical relationships that allow the precise evaluation of the influence of the main geometric elements of the mechanisms on their dynamics
O5: Numerical simulation of the functioning of the mechanisms	**R5**: Realization of an extensive and detailed numerical simulation for one of the inertial propulsion mechanisms in the SolidWorksMotion software	**C5**: Elaboration and running complex numerical simulation scenarios, interpretation and critical analysis of simulation

Objectives of the thesis	Achievements obtained within the thesis	Personal contributions
	environment, validating the kinematic and dynamic behavior of the device	results to validate theoretical concepts
O6: Comparison of analytical calculations with simulation results	**R6**: Identification and choice of the optimal constructive option, based on objective criteria derived from the comparison and validation of analytical calculations with the results of the numerical simulation	**C6**: Performing an exhaustive comparative analysis between the analytical data and the numerical results.
O7: Comparison of the results of experimental measurements with those of simulations	**R7**: Perform a detailed and rigorous comparison between the experimental results and those of the numerical simulation, clearly identify the agreement and definitively validate the numerical model.	**C7.1**: Development of the experimental methodology, performing precise and rigorous measurements for the experimental validation of the ability of the inertial propulsion device to generate unidirectional linear motion. **C7.2**: Detailed comparative analysis and interpretation of the results, which demonstrated a very good concordance, with maximum differences below 10%.

As a result of the research carried out, the following future research directions are proposed, but without limiting the further possibilities of exploration:

- Advanced optimization of mechanisms for further size reduction, increased energy yield and improved durability;
- In-depth study of the impact of various constructive changes, such as the implementation of additional mechanisms to increase operational stability and reliability;

- Investigating the influence of various types of lubricants and lubrication techniques on the dynamic performance and durability of mechanisms;
- Making a prototype of the reaction moment reduction system and conducting experimental tests;
- Study of how the moment additionally generated by the reaction moment reduction system is influenced, if the transmission ratio of the synchronous belt is different from 1.
- Research the applicability of advanced materials and the use of modern manufacturing technologies, such as 3D printing, to significantly increase efficiency and reduce production costs and time.

The results of the research have been presented at relevant national and international conferences and symposia in the field of mechanical engineering and robotics, being published in indexed journals ISI, SCOPUS and BDI. In addition, the active participation in the thematic seminars and workshops organized within the Doctoral School of Engineering (https://eng.ubbcluj.ro/?page_id=405#tab-id-8) allowed me to exchange ideas and experiences with other doctoral students or researchers and professionals in the field. These activities have contributed essentially to the visibility, recognition and impact of the research carried out within the national and international academic and professional community.

A. Papers published in WOS journals [191, 192]:

A1. **Timofte, S.**; Korka, Z.I.; Gerocs, A.; Komjaty A.; Bulzan, F. *Dynamic calculation of an innovative device for reducing reaction torque,* Calculation 2024, Vol. 12(11) 219 (WOS:001364149100001).

A2. **Timofte, S.**; Miclosina, C.O.; Cojocaru, V.; Gerocs., A; Korka Z.I. *Inertial propulsion of a mobile platform driven by two eccentric bodies*, -Applied Sciences, 2023, vol. 13 (17), 9511 (WOS:001063642600001).

B. *Papers presented at international conferences* [193]:

B1. **Timofte, S.**; Korka, Z.I.; Gerocs, A.; Wisznovszky, S.; Sfetcu, C.R. *Kinematic and dynamic investigation of a new inertial propulsion unit*. Presented at the International Conference on Science, Technology, Engineering And Economy (ICOSTEE 2022), 24 March 2022, Szeged, Hungary and published in Analecta Technica Szegedinensia, 2022, Vol. 16(1), p. 27-32.

C. Papers published in BDI indexed journals [194- 196]:

C1. **Timofte, S.**; Cindea, L.; Hațiegan, C. *Robot for tracking rectilinear motion*, Studia Universitas Engineering, 2022, Vol. 67 (1), p. 246-255.

C2. **Timofte, S.**; Cindea, L.; *Design and testing of a mini robot for tracking a welding technology path*, Robotics & Management, 2021, Vol. 26(1), p. 17-21.

C3. **Timofte, S.**; Cindea, L.; Hațiegan, C. *Controlling a vehicle through a smartphone application,* Annals of the "Constantin Brâncuși" University of Târgu Jiu, Engineering Series, 2021, Vol. 2, pag. 39-43.

BIBLIOGRAPHY

[1] Dean, R. Innovations in inertial drive mechanisms. International Journal of Propulsion Technology 2017, 5(3), 221-230.

[2] Thornson, J. Experimental evaluation of inertial actuation performance. Vehicle System Dynamics 2018, 56(11), 1620-1635.

[3] Provatidis, C.G. Review of inertial propulsion systems. Journal of Research in Mechanical Engineering 2014, 6(1), 15-28.

[4] Robertson, G.; Webb, J. Inertial propulsion mechanism. Acta Astronautica 2015, 117, 156-167.

[5] Yang, L.; Chen, Y.; Guo, J. Advances in inertial propulsion techniques. Robotics and Autonomous Systems 2019, 120, 103-112.

[6] Webb, J.; Wilson, K. Future Directions in Inertial Propulsion Technology. Aerospace Science and Technology 2022, 120, 107264.

[7] Zhao, F.; Shi, G. Application of inertial propulsion systems. Ocean Engineering 2020, 210, 107496.

[8] Ren, H.; Zhang, Y.; Liu, C. Optimization of inertial propulsion mechanisms. Journal of manufacturing processes 2021, 64, 343-352.

[9] Allan Jr., J. The Reality of Inertial Propulsion. NASA Technical Reports 2005.

[10] Booden, M.A. Electromagnetic inertial propulsion mechanisms. International Journal of Advanced Engineering Technology 2016, 7(4), 125-131.

[11] Tajmar M. Advanced Space Propulsion Systems. Springer: New York-Vienna, 2002.

[12] Bruno, C.; Accettura, A.G. (Eds.) Advanced Propulsion Systems and Technologies: Today to 2020, Volume 223 Advances in Astronautics and Aeronautics, American Institute of Aeronautics and Astronautics, Virginia, 2008.

[13] Millis, M.G.; Thomas, N.E. Response to Mechanical Antigravity, NASA/TM-2006-214390, AIAA-2006-4913, December 2006. Available at:

[14] Minetti, A.E.; Ardigó, L.P. Dumbbells used in the ancient Olympic long jump. Natura 2002, 420, 141–142.

[15] Provatidis, C.G. Biomechanics simplified for a possible explanation of the ancient Greek long jump using dumbbells. Universal Journal of Engineering Sciences 2013, 1(1), 5-16. https://doi.org/10.13189/ujes.2013.010102.

[16] Provatidis, C.G. On the maximum length of the standing long jump using dumbbells. International Journal of Research and Multidisciplinary Studies 2018, 1(3), 153-169.

[17] Citizendium: http://en.citizendium.org/wiki/Reactionless_propulsion

[18] Todeschini M. Centrifugal propulsive force motor powered by dissociated water with automatic gradual speed variation. Kingdom of Italy, Ministry of Corporations, Industrial Patent No. 312496, 17 November 1933 (see the first two pages of the patent on the website

[19] Dean N.L. System for converting rotary motion to unidirectional motion. U.S. Patent 2,886,976, May 19, 1959.

[20] Dean N.L. System of Variable Oscillators. U.S. Patent 3,182,517, May 11, 1965.

[21] Campbell, J., Jr. Space Drive Problem. Amazing Science and Fiction, June 1960, 83-106.

[22] Dempewolff, R.F. Built-in Wing Engine," Popular Mechanics, Sept. 1961, 131–134 and 264–266.

[23] Burridge, G. Towards Antigravity", Rosicrucian Digest, Vol. XL, April 1962, 136-139.

[24] Davis, W.O. The Fourth Law of Motion, analogous 69(3): 83-104 (May 1962). The extract is available at:

[25] Stine, G.H. Detesters, Phasers and Dean Drives", Analog, iunie 1976, 75.

[26] Campbell, J.W. (1962) - Interviu de Fred Lerner: E010&ab_channel=FANACFanHistory

[27] Stepanov, G.Yu., "Why is it impossible to have the "dean's apparatus"?", Jour. Priroda, vol. 7, 1963, pp. 85-91 (in Russian).

[28] Goncharevich, I.F. The dynamics of vibrational transport. Nauka, Moscow (1972); p. 244 [in Russian]

[29] Blekhman I.I., "Vibrational Mechanics: Nonlinear Dynamic Effects, General Approach, Applications", World Scientific, Singapore, 2000 (p.15 and p.19).

[30] Di Bella A. Apparatus for transmitting the motion of an organism, U.S. Patent 3,404,854 (filed May 5, 1967 and granted October 8, 1968).

[31] Di Bella, A. On the propulsive effects of a rotating mass. In: R. D. Cooper and S. W. Doroff (Eds.), Proceedings Seventh Symposium Naval Hydrodynamics, August 25-30, 1968, Rome, Italy (Bureau of Naval Research – Department of the Navy, Arlington, Va.), pp. 1373-1396.

[32] Online: https://en.wikipedia.org/wiki/Viviani%27s_

[33] Therriault C. Wing Movement for Ornithoptera and Similar Apparatus, U.S. Patent No. 6.227.483 B1, 8 May 2001.

[34] Kuchinov, The Knots of E. Quesalid: A Guide to the Esoteric Research Institutes of the Soviet Union. https://sreda.v- a-c.org/en/read-01

[35] Tolchin V.N. Sily inertsii kak istochnik postupatel'nogo dvizheniia (Perm: Permskoe knizhnoe izdatel'stvo, 1977). Translation: Inertial forces as a source of translational motion.

[36] Copia originală a scurtmetrajului Tolchin Tolchin Drive:https://www.youtube.com/watch?v=DOXoaYs790M&ab_channel=stclairtechrdhttps://www.youtube.com/watch?app=desktop&v=u9-wdV32hos&ab_channel=AltPropulsion

[37] Kononenko, V. O., Vibrating systems with a limited power supply. Iliffe Books Ltd: London, 1969, p.24. Translated from Russian: V. O. Kononenko, Oscillatory systems with limited excitation. Moscow, Nauka, 1964.

[38] Blekhman, I.I. Timing in Science and Technology. ASME Press: New York, 1988 (in English, translated from Russian 1981).

[39] Laithwaite, E.R. Wheelless Propulsion, 2nd edition. English Universities Press: London, 1970.

[40] Wikipedia: https://en.wikipedia.org/wiki/Eric_Laithwaite

[41] Laithwaite, E.R. The Engineer Through the Mirror | The royal institution: science lives here. Retrieved January 7, 2024. (Looking-glass-house-1974)

[42] Bruce De Palma: https://en-academic.com/dic.nsf/enwiki/1876830

[43] DePalma, n. The Tuning Fork Experiment, in: R.L. Dione, 1976 (ISBN 553-02723-150); See also:

[44] http://rexresearch.com/depalma2/depalm.htm, https://depalma.pairsite.com/gyrodrop.html.

[45] https://depalma.pairsite.com/gyrodrop.html.

[46] Hoshino M.U.S. Patent for "Centrifugal Power Propulsion," No. 20050139022 (Filed January 7, 2004; Published: June 30, 2005).

[47] Hampton, S.M., Din Dean Drives și Davis Mechanics: Inertial Propulsion and the Manipulation of Time in Symmetrical Systems © , Ebook, Apple Communications, London Mills, Illinois, 2007, 2011 (ISBN 518 373).

[48] Hampton, S.M. Asymmetric momentum. AIAA 2022-4391. ASCEND 2022 (October 24-26, 2022, Las Vegas, Nevada and online). Session: Frontiers in the propulsion of deep space. Watch the video: https://doi.org/10.2514/6.2022-4391.vid

[49] Tsiriggakis, V.Th.; Provatidis C.G.; Frigas U.S. Patent Application for an "Anti-Gravity Mechanism", no. 61/110,307, submitted on October 31, 2008.

[50] Provatidis, C.G.; Tsiriggakis, V.T. A new concept and design aspects of an "anti-gravity" propulsion mechanism based on inertial forces. Proceedings of the 46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibition, Nashville, TN, July 25-28, 2010 (AIAA Paper 2010-6684).

[51] Provatidis, C.G. A device that can produce net momentum using rotating masses. Engineering 2020, 2(8), 648- 657.

[52] Valone, T. Inertial propulsion: concept and experiment, Part I, Proc. IECEC, 1993.

[53] Valone, T. Inertial Propulsion: Concept and Experiment, Part II, Intersocietal Energy Conversion Engineering Conference (August 7, 1994 – August 12, 1994, Monterey, CA, USA), AIAA-94-4167-CP, pp. 1484-1489. https://doi.org/10.2514/6.1994-4167

[54] Valone, T.; Cox, J. Inertial propulsion: patent collection. Integrity Research Institute: Washington, D.C., 2008.

[55] Valone T.F. Eric Laithwaite Report: Gyromagnetic Engineering Genius – Publications, Inventions & News Clips (IRI PR-02-005), Integrity Research Institute: Beltsville, MD, December 2006.

[56] Almesallmy, M. Experimental and analytical investigation of inertial propulsion mechanisms and simulation of the movement of rigid-multibody mechanical systems. Doctoral dissertation. University of Rhode Island, 2006.

[57] Guiad, D.; Nilvetti, F.; Pappalardo, CM Influence of dry friction on the dynamics of the trolley pendulum. International Journal of Mechanics 2009, 3(2), 31-38.

[58] Provatidis, C.G. Some problems regarding inertial propulsion mechanisms using two counter-rotating masses. Theory of Mechanisms and Machines 2010, 8(1), pp. 34-41. Download from:

[59] Provatidis, C.G. A Study of the Mechanics of an Oscillating Mechanism, International Journal of Mechanics 2011, 5(4), 263-274. Online at:

[60] Provatidis, C.G. An overview of the mechanics of oscillating mechanisms. American Journal of Mechanical Engineering 2013, 1(3), 58-65. https://doi.org/10.12691/ajme-1-3-1

[61] Provatidis, C.G. Repeated vibrational motion using an inertial drive. Journal of Vibration and Acoustics Research 2019, 1(1). Online:

[62] Provatidis, C.G. On the inertial propulsion of floating objects using counter-rotating masses. Mechanics Research Communications 2014, 62, 117–122, https://doi.org/10.1016/j.mechrescom.2014.09.004 Closely related online videos:

[63] Majewski. T. Vibratory forces and synchronization in physical systems. Mechanical Engineering, Technology and Development 2013, 4(4), 119 – 128.

[64] Ikuta, K., Aritomi, S. and Kabashima, T. Small silent linear cybernetic actuator driven by a piezoelectric device with electromagnetic clamp. [1992] Proceedings IEEE Micro Electro Mechanical Systems, Travemunde, Germany, 1992, pp. 232-237, https://doi.org/10.1109/MEMSYS.1992.187723.

[65] Aoyama, H., Iwata, F., and Sasaki, A. Flexible desktop manufacturing system with miniature mobile robots—miniature robots with microtools and sensor. Proceedings of the 1995 IEEE International Conference on Robotics and Automation, Nagoya, Japan, 1995, pp. 660-665 vol.1, https://doi.org/10.1109/ROBOT.1995.525359.

[66] Zesch, W.; Buchi, R.; Codourey, A.; Siegwart, R. Inertial drives for micro and nanorobots: two novel mechanisms. Proc. SPIE Microrobotics and Micromechanical Systems, Philadelphia, USA, pp. 80-88, October 18, 1995. https://doi.org/10.1117/12.228638

[67] Buchi, R.; Zesch, W.; Codourey, A.; Siegwart, R. Inertial drives for micro and nanorobots: analytical study. Proc. SPIE Vol. 2593, p. 89-97, Microrobotics and Micromechanical Systems, 1995. https://doi.org/10.1117/12.228639

[68] Yoshikawa, H.; Kagiwada, T.; Harada, H.; Mimura, M. Improvement of the propulsion mechanism based on inertial force. In: F. Kimura and K. Horio (eds.), Towards the synthesis of micro-/nano-systems. Springer: London, 2007, pp. 333-334.

[69] Ju, J.; Wang, Q.; Zhang, K. Design and analysis of a new micro-robot driving platform. Proc IMechE-Part C: Journal of Mechanical Engineering Science 2019, 233(11), 3849-3857. https://doi.org/10.1177/0954406218802314

[70] Vatholomeos, P.; Papadopoulos, E. Dynamics, design and simulation of a new micro-robotic platform using micro-vibration actuators. ASME Journal of Dynamic Systems, Measurement and Control 2006, 128(1), 122-133. https://doi.org/10.1115/1.2168472

[71] Vartholomeos, P.; Papadopoulos, E. Analysis and experiments on the force capabilities of centripetal force-driven microrobotic platforms. IEEE Transactions on Robotics 2008, 24(3), 588-599. https://doi.org/10.1109/TRO.2008.919298.

[72] Provatidis, C.G. Design of a propulsion cycle for endless sliding on friction ground using rotating masses. Universal Journal of Mechanical Engineering 2014, 2 (2), 35 43. https://doi.org/10.13189/ujme.2014.020201

[73] Provatidis C.G. Dean Driving Mechanics on the Friction Ground, Journal of Mechanical Design and Vibration 2014, 1(1), 10-19. Online at: https://pubs.sciepub.com/jmdv/1/1/3/index.html, doi:10.12691/jmdv-1-1-3

[74] Provatidis C.G. Unidirectional motion using rotating masses along figure-eight trajectories, Journal of the Brazilian Society of Mechanical Sciences and Engineering 2015, 37(1), 397–409. https://doi.org/10.1007/s40430-014-0154-y

[75] Provatidis, C.G. Progress in an antigravity mechanism using inertial masses. Proceedings Space, Propulsion & Energy Sciences International Forum (SPESIF-2011) [CR-ROM], presented on March 15-17, 2011, University of Maryland, College Park, MD, USA.

[76] Provatidis, C.G. Older and Contemporary Attempts at Inertial Propulsion. The General Science Journal, November 14, 2011. Online:

[77] Gamble, M. History of Boeing Control Moment (CMG) gyroscopes. Presentation at the Seventh International Conference on Future Energy (COFE7), July 30 – August 1, 2015, Embassy Suites, Albuquerque New Mexico (Boeing 15-00051-EOT).

[78] Dmitriev A. L. and Snegov V. S.. Mass measurements: weighing a mechanical gyroscope with horizontal and vertical orientation of the axis of rotation. Measurement Techniques 2001, 44(8), 831-833 (Translated from Izmeritel'naya Tekhnika, No. 8, pp. 33-35, August, 2001. Original article sent on April 3, 2001).

[79] Dmitriev A. L. Frequency dependence of rotor free-fall acceleration and inertial and gravitational mass inequality. January 2011, arXiv:1101.4678 [pdf].

[80] Dmitriev, A.L.; Snegov, V.S. Mass measurements: weighing a mechanical gyroscope with horizontal and vertical orientation of the axis of rotation. Measurement Techniques 2001, 44, 831–833. https://doi.org/10.1023/A:1012900502477

[81] Dmitriev, A.L. Physical justification of an opportunity for artificial change in body weight. Physics Procedia 2012, 38, 150–163. https://doi.org/10.1016/j.phpro.2012.08.019

[82] Dmitriev, A.L. High-frequency gravimetry perspectives. International Journal of Circuits, Systems, and Signal Processing 2015, 9, 275–280. Online at: 37.pdf

[83] Samokhvalov, V.N. Research and measurement of the effects of force during mass-dynamics interaction. Galilean Electrodynamics & GED East 2015, 26(1), 3-11.

[84] Samokhvalov, V.N. The interaction of the non-electromagnetic force in the presence of rotating masses in vacuum. International Journal of Unconventional Science 2016, Issue E1, 68-80. http://www.unconv- science.org/en/e1/samokhvalov/

[85] Allen, D.P. Jr.; Dunning-Davies, J. Neo-Newtonian mechanics with extension to relativistic velocities; Part 1: Non-Radiative Effects, 18th Edition, Kindle Direct Publishing, 2023.

[86] Pais, S. C. Directional motive force generation device. U.S. Patent US20190331096A1, filed on April 17, 2018 and issued on October 31, 2019. United States Patent and Trademark Office. https://patents.google.com/patent/US20190331096A1

[87] Lukanov, A.I. (2015). Using inertial forces as a source of forward motion. Machine mechanics. Available at: https://www.researchgate.net/publication/314077999_USING_INERTIAL_FORCES_AS_A_SOURCE_OF_FORWARD_MOTION

[88] Murad, P.A. (2015). New Frontiers in Space Propulsion Science, Part II. Available: https://www.researchgate.net/publication/285417602_New_frontiers_in_Space_Propulsion_Science_Part_II

[89] Marsh Jr., R.O. (1995). Centrifugal force drive machine. U.S. Patent US5388470A, February 7, 1995. Available at: https://patents.google.com/patent/US5388470A.

[90] Cuff, U.S. Patent No. 3.998.107, December 1976, United States Patent and Trademark Office. https://patents.google.com/patent/US3998107A/en

[91] Kieper, U.S. Patent No. 3,964,322, June 1976, United States Patent and Trademark Office. https://patents.google.com/patent/US3964322A/en

[92] Majima, U.S. Patent No. 3,871,617, March 1975, United States Patent and Trademark Office. https://patents.google.com/patent/US3871617A/en

[93] Komura, M. and Toyo Communication Equipment Co. Ltd. (2001). *Traction generator and moving body device*. The European patent EP1114930A1. European Patent Office. Published July 11, 2001. Available at: https://patents.google.com/patent/EP1114930A1/en

[94] Cook, H. (1991). *Inertial propulsion system*. U.S. Patent No. 5,054,331. United States Patent and Trademark Office. Published on October 8, 1991. Available at: https://patents.google.com/patent/US5054331A/en

[95] Bull, N. (1983). *Gyroscopic propulsion system*. U.S. Patent No. 4,409,856. United States Patent and Trademark Office. Published on October 18, 1983. Available at: https://patents.google.com/patent/US4409856A/en

[96] Yamazaki, K. (1995). *Propulsion mechanism using rotating weights*. Open Japanese patent application no. JPH0749079A. Japan Patent Office. Available at: https://patents.google.com/patent/JPH0749079A/en

[97] Nakamura, S. (1999). *Rotary drive system for unidirectional force generation*. Open Japanese patent application no. JPH11107905A. Japan Patent Office. Available at: https://patents.google.com/patent/JPH11107905A/en

[98] McCutchen, J. M. (2005). Propulsion apparatus that uses centrifugal force. U.S. Patent No. US20050139022A1. Filed on December 23, 2003 and published on June 30, 2005 https://patents.google.com/patent/US20050139022A1/en?oq=McCutchen%2c+J.+M.+(2005).+Propulsion+apparatus+using+centrifugal+force.+Patent+USA+no.+US20050139022A1.

[99] Stroia, M. L. (2009). *Contributions to the calculation of the durability and reliability of planetary gears*. Ph.D. thesis, Polytechnic University of Timișoara. Available at: https://dspace.upt.ro/jspui/bitstream/123456789/4898/1/BUPT_TD_Stroia%20Mihaela%20Luminita.pdf

[100] National Institute for Research and Development for Electrical Engineering ICPE-CA. (2009). *Scientific Report 2008*. Bucharest, Romania. Available at: https://www.icpe-ca.ro/icpe-ca/rapoarte-activitate/raport-stiintific-2008.pdf

[101] US20060123937A1 - Tsepenyuk, M. (2006). *Centrifugal generator of a traction force for aviation and space aircraft*. Available at: https://patents.google.com/patent/US20060123937A1/en

[102] Frolov, A. V. (2017). *New aerospace technologies*. Tula State University Publishing House. Available at: https://www.researchgate.net/publication/356524014

[103] Lovell, R. R. and Nieberding, W. C. (1966). *Tensile measurement of SERT I ion thrusters*. NASA technical report. Available at: https://ntrs.nasa.gov/api/citations/19660013633/downloads/19660013633.pdf

[104] Orth, C. D., et al. (1987). *Interplanetary propulsion using inertial fusion*. Lawrence Livermore National Laboratory, NASA. Available at: https://ntrs.nasa.gov/api/citations/19880003158/downloads/19880003158.pdf

[105] Sandu, C., & Brăşoveanu, D. (2007). *Sonic-Electromagnetic-Gravitational Spacecraft – Part 1-10*. Available at: https://www.researchgate.net/publication/305316103

[106] Smith, D. S. (2008). Propulsion device that uses the conversion of rotary motion into a unidirectional linear force. Patent US20080060460A1. Available at: https://patents.google.com/patent/US20080060460A1/en. Published: March 13, 2008.

[107] Kuff, D. (1976). Rotary boom propulsion system. U.S. Patent No. 3,968,700. Available at: https://patents.google.com/patent/US3968700A/en.

[108] Valles, R. (1980). Counter-rotating boom drive system. U.S. Patent No. 4,238,968. Available at: https://patents.google.com/patent/US4238968A/en.

[109] Helavuo, K. U. (2013). Device for supplying propulsive force. WO2013087991A1. World Intellectual Property Organization. Available at: https://patents.google.com/patent/WO2013087991A1/en. Published on: 20 June 2013.

[110] McMahon, J. C. (1992). Inertial propulsion system. US5167163A. Available: https://patents.google.com/patent/US5167163A/en.

[111] Thorson, B. R. (1986). Propulsion force generating device. US4631971A. Available: https://patents.google.com/patent/US4631971A/en.

[112] Siriphant, A. J. (2008). Method and device for generating a force vector. WO2008153397A1. WIPO. Available at: https://patents.google.com/patent/WO2008153397A1/en. Published: 18 December 2008, Geneva.

[113] Boehm, M. (1999). Device for generating propulsion by means of rotating masses. DE19750235A1. Available at: https://patents.google.com/patent/DE19750235A1/en

[114] Frolov, A. V. (2017). New aerospace technologies. The research gate. Available at: https://www.researchgate.net/publication/356524014

[115] Kim, S. H. (2001). Centrifugal propulsion system. WO2001055592A1. WIPO. Available at: https://patents.google.com/patent/WO2001055592A1/en. Published on: August 2, 2001, Geneva.

[116] Lukanov, I. (2015). Using inertial forces as a source of forward motion. Machine mechanics. Available at: https://www.researchgate.net/publication/314077999_USING_INERTIAL_FORCES_AS_A_SOURCE_OF_FORWARD_MOTION

[117] Wang, D., et al. (2023). Research progress towards the engineering feasibility of centrifugal nuclear thermal rocket. The 74th International Congress of Astronautics. Available at: https://www.researchgate.net/publication/374501453

[118] Fréchette, L. G., et al. (2000). Gas turbines the size of a shirt button: the engineering challenges of high-speed rotating machines. Available at: https://www.researchgate.net/publication/247511488

[119] Opalek, A. A. (2018). Rotary propulsion engine system. US20180290770A1. U.S. Patent Application Publication. Available at: https://patents.google.com/patent/US20180290770A1/en. Published on: 11 October 2018.

[120] Booden, J. D. (1998). Electromagnetically driven traction generator. US5782134A. Available at: https://patents.google.com/patent/US5782134A/en.

[121] Kellogg, H. D. (1965). Gyroscopic inertial spatial drive. US3203644A. Available: https://patents.google.com/patent/US3203644A/en.

[122] Fulop, C. (1988). Steering wheel. US4788882A. Available at: https://patents.google.com/patent/US4788882A/en.

[123] Gerõcs, A., Korka, Z.-I., Bíró, I., & Nedelcu, D. (2019). *A dynamic analysis of an inertial propulsion system with rotating balls*. In: Proceedings of the 17th International Conference on Mechanical Engineering, Svratka, Czech Republic, pp. 130-133. Institute of Thermomechanics, Czech Academy of Sciences. Place: Svratka, Czech Republic. May 2019. Related: https://www.researchgate.net/publication/342708896

[124] Nedelcu, D., Korka, Z.-I., Gerõcs, A., & Mihon, L. (2018). *Investigation of a frictional drive mechanism using a kinematic model*. Mechanics and Applied Materials, Vol. 880, pp. 87-94.

Trans Tech Publications. Stafa-Zurich, Switzerland. June 2018. Link: https://www.scientific.net/AMM.880.87

[125] Bíró, I. (2006). *Mathematical and physical simulation of dynamical systems*. Acta Technica Jaurinensis, 1(2), 65–72. Link: https://www.emk.sze.hu/~acta/volumes/2006/ActaVol1No2/BIRO.pdf

[126] Juhász, Á. (2002). *Cinematica analitică*. University of Miskolc Press. Link: https://www.uni-miskolc.hu

[127] Horváth, G. (2008). *Kinematics and solid-body dynamics*. University of Miskolc. Related: https://www.uni-miskolc.hu

[128] Geröcs A., Gillich G.R., Nedelcu D., Korka Z.I., "Multibody inertial propulsion with symmetrically placed balls rotating on eccentric rails", Simetrie, 2020, 12, 1422. https://www.researchgate.net/publication/343899212_A_Multibody_Inertial_Propulsion_Drive_with_Symmetrically_Placed_Balls_Rotating_on_Eccentric_Trajectories

[129] Newton I., Principia Mathematica, 1687. https://www.researchgate.net/publication/287124312_Isaac_Newton_Philosophiae_naturalis_principia_mathematica_first_edition_1687

[130] Gillich G.R., Engineering Mechanics: Dynamics, Springer, 2014.

[131] NASA Reports, Advances in Propulsion, NASA, 2018. (https://ntrs.nasa.gov/citations/20180003008

[132] Gillich N., Chioncel C.P., Applied Mechanics, 2015. https://www.researchgate.net/publication/279961313_A_multi-resolution_based_method_to_precise_identify_the_natural_frequencies_of_beams_with_application_in_damage_detection

[133] European Space Agency Reports, ESA, 2019. https://www.esa.int/About_Us/ESA_Annual_Report_2019

[134] Journal of Aerospace Engineering, Elsevier, 2021. https://www.sciencedirect.com/journal/aerospace-science-and-technology

[135] Geröcs A., Korka Z.I., Biro I., Cojocaru V., 2019, Investigarea analitică a unui sistem de propulsie inerțială folosind mase rotative, Proceedings of the International Conference on Applied Sciences ICAS2019, Hunedoara, România, Mai 9-11, Journal of Physics: Conference Series 1426, 012031. https://www.researchgate.net/publication/338349431_Analytical_investigation_of_an_inertial_propulsion_system_using_rotating_masses

[136] Shipov G.I., 1998, A Theory of the Physical Vacuum. Theory, experiments and technologies, Moscow, Russia. https://archive.org/details/g.-i.-shipov-a-theory-of-physical-vacuum

[137] Dean D., 2013, Inertial Propulsion: The Holy Grail of Space Travel, New Scientist, Vol. 219.

[138] Frolov A.V., 2002, Inertial Propulsion Technologies, New Energy Technologies, Issue 1, pp. 5-8. https://www.researchgate.net/publication/377769695_Inertial_Propulsion_Devices_A_Review

[139] Kononenko, V.O. Vibration Systems with a Limited Power Supply, Iliffe Books Ltd, London, 1969.

[140] Gardiner, E.N.Athletics in the Ancient World. Dover, New York, 2002.

[141] Gursky, V.; Kuzio, I.; Krot, P.; Zimroz, R. Energy-saving inertial drive for dual-frequency excitation of vibrating machines. Energies 2021, 14, 71.

[142] Dean, N.L. System for Converting Rotary Motion to Unidirectional Motion, U.S. Patent 2,886,976, issued 1959.

[143] Cuff, C. I. Device for converting rotary motion into unidirectional motion. U.S. Pat. No. 4095460, issued in 1978.

[144] Dobos. E. M. Propulsion device. U.S. Pat. No. 4579011, issued in 1986.

[145] Deschamplain, D. Motion transmission system. US Pat. No. 6259177B1, issued in 2001.

[146] Murray, L. D. Mechanical force generator. US Pat. No. 6290622B1, issued in 2001.

[147] Loukanov, I.A. Vibration propulsion of a mobile robot. IOSR Journal of Mechanical and Civil Engineering 2015, 12(2), pp. 23-33. https://www.researchgate.net/publication/281435878_Vibration_Propulsion_of_a_Mobile_Robot_IOSR_Journal_of_Mechanical_and_Civil_Engineering_Vol_12_Issue_2_Version_II_March_-_April_2015

[148] Halliday, D.; Resnick, R.; Walker, J. Foundations of Physics, 12th edition; Wiley: New York, NY, USA, 2021; pages 101-131.

[149] Colli, A.; Zanotti, A.; Giuseppe, G. Experimental investigation in the wind tunnel on the rotor-rotor aerodynamic interaction in the compound helicopter configuration. Aerosp. Sci. Technol. 2024, 109420. [Cross Ref]

[150] Gunaltili, E.; Ekici, S.; Kalkan, A.; Gocmen, F.E.; Kale, U.; Yilmazoglu, Z.; Karakoc, T.H. Conceptual design and optimization of a sustainable and environmentally friendly archetypal helicopter within selection criteria and limitations. Heliyon 2023, 9, e17369. [Cross Ref] [PubMed]

[151] Balli, O. Exergetic, sustainable and environmental evaluations of a turboshaft engine used on helicopter. Energy 2023,276, 127593. [Cross Ref]

[152] Castillo-Rivera, S.; Tomas-Rodriguez, M. Helicopter modeling and the study of the accelerated rotor. Adv. Eng. Softw. 2018, 115, 52–65. [Cross Ref]

[153] Surette, J. 5 Reasons why the Boeing CH-47 "Chinook" helicopter is still going strong after six decades. Published on September 26, 2023. Available online: https://simpleflying.com/boeing-ch-47-chinook-longevity-aspects-list/ (accessed July 28, 2024).

[154] Duan, D.; Leng, G.; Gao, J.; Feng, X.; Li, J. Load distribution strategy for multi-lift helicopter system based on power consumption and robust adaptive game control. Chinese. J. Aeronaut. 2023, 36, 268–285. [Cross Ref]

[155] Geng, J.Y.; Langelaan, J.W. Cooperative transport of a suspended load using load conduction control. J. Guid. Control Dyn. 2020, 43,1313–1331. [Cross Ref]

[156] Chopra, O.; Ghose, D. Distributed control for multiple UAV transport of suspended loads. In AIAA SCITECH 2022 Forum Proceedings, San Diego, CA, USA, January 3-7, 2022

[157] Mokhtar, T.; Soltan, T.; Abdelrahman, M.M. Improving helicopter performance by mitigating retracting blade jam using active flow control. Sci. Afr. 2023, 21, e01888.

[158] Yu, D.; Che, T.; Zhang, H.; Li, C.; Wang, C.; Wang, Z. Optimization of land locomotion of wavy-finned amphibious robots: asynchronous control and phase difference optimization. Ocean Eng. 2024, 303, 117755. [Cross Ref]

[159] Wu, J.; Yao, Y. Design and analysis of a new walking vehicle based on the foot mechanism with variable topologies. J. Mech. Mach. Theory 2018, 128, 663–681. [Cross Ref]

[160] Scales, J.; Coleman, D.; Brown, M. The multiday load trolley decreases the ability to attenuate ground reaction force by reducing ankle torque output. Appl. Ergon. 2022, 101, 103717. [Cross Ref] [PubMed

[161] Chan, V.C.H.; Ross, G.B.; Clouthier, A.L.; Fischer, S.L.; Graham, R.B. The Role of Machine Learning in the Primary Prevention of Work-Related Musculoskeletal Disorders: A Review of Purpose. Appl. Ergon. 2022, 98, 103574. [Cross Ref]

[162] Coulombe, M. Differential displacement device under simultaneous and repetitive electromagnetic repulsive forces. U.S. Patent No. 7,909,669, May 10, 2010.

[163] Benjamin, P.M. Centrifugal thrust motor. U.S. Patent No. 3,750,484, August 7, 1973.

[164] Booden, J.D. Electromagnetically Driven Traction Generator. U.S. Patent No. 5,782,134, July 21, 1998.

[165] Cuff, C.I. Device for converting rotary motion into unidirectional motion. U.S. Patent No. 4,095,460, June 20, 1978.

[166] Dobos, E.M. Propulsion apparatus. U.S. Patent No. 4,579,011, April 1, 1986.

[167] Farrall, A.W. Inertial propulsion device. U.S. Patent No. 3,266,233, August 16, 1966.

[168] Fulop, C. Volant. U.S. Patent No. 4,788,882, December 6, 1988.

[169] Haller, P. Propulsion apparatus. U.S. Patent No. 3,177,660, April 13, 1965.

[170] Kellogg, H.D. Gyroscopic Inertial Spatial Actuation. U.S. Patent No. 3.203.644, August 31, 1965.

[171] Mendez Llamozas, J.D. Direct thrust propulsion unit. U.S. Patent No. 2,636,340, April 28, 1953.

[172] Nord, H. Apparatus for producing a force. U.S. Patent No. 4,712,439, December 15, 1987.

[173] Oades, R.A. Apparatus for generating a propulsive force. U.S. Patent No. 5,890,400, April 6, 1999.

[174] Shimshi, E. Apparatus for the transformation and conservation of energy. U.S. Patent No. 5,673,872, October 7, 1997.

[175] Schnur, N.J. The method and apparatus for propelling an object by an unbalanced centrifugal force with continuous motion. U.S. Patent No. 3,979,961, September 14, 1976.

[176] Deschamplain, D. Motion transmission system. U.S. Patent No. 625,917,7B1, July 10, 2001.

[177] Marsh, R.O. Centrifugal drive machine. U.S. Patent No. 5,388,470, February 14, 1995.

[178] Murray, L.D. Mechanical Force Generator. U.S. Patent No. 629,062,2B1, September 18, 2001.

[179] Kunz, W.T. Centrifugal propulsion system. U.S. Patent No. 5,937,698, August 17, 1999.

[180] Woltermg, H.M. Vibrator system with rotating eccentric weights. U.S. Patent No. 5,388,469, February 14, 1995.

[181] Dean, N.L. System for converting rotary motion to unidirectional motion. U.S. Patent No. 2,886,976, May 19, 1959.

[182] Thornson, B.R. Apparatus for the development of propulsive force. U.S. Patent No. 4,631,971, December 30, 1986.

[183] Goncharevich, I.F. Vibrational Transport Dynamics; Nauka: Moscow, Russia, 1972; p. 244. (In Russian)

[184] Gerocs, A.; Gillich, G.R.; Nedelcu, D.; Korka, Z.I. A multibody inertial propulsion with symmetrically placed balls rotating on eccentric trajectories. Symmetry 2020, 12, 1422. [Cross Ref]

[185]Blekhman, I.I. Vibrational Mechanics: Nonlinear Dynamic Effects, General Approach, Applications; World Scientific: Singapore, 2000;pp. 15, 19.

[186] Gerocs, A.; Korka, Z.I.; Biro, I.; Cojocaru, V. Analytical investigation of an inertial propulsion system using rotating masses. J. Phys. Conf. Ser. 2020, 1426, 012031. [Cross Ref]

[187] Kononenko, V.O. Vibrating systems with a limited power supply; Iliffe Books Ltd.: London, UK, 1969; p. 24. (In English)

[188] Blekhman, I.I. Synchronization in Science and Technology; ASME Press: New York, NY, USA, 1988; (In English, translated from Russian).

[189] Timofte, S.; Miclosina, C.O.; Cojocaru, V.; Gerocs, A.; Korka, Z.I. Inertial propulsion of a mobile platform driven by two eccentric bodies. Appl. Sci. 2023, 13, 9511. [Cross Ref]

[190] Majewski, T. Vibratory Forces and Timing in Physical Systems. Mechanical Engineer Tecnol. Development. 2013, 4, 119–128.

[191] Timofte, S.; Korka, Z.I.; Gerocs, A.; Komjaty A.; Bulzan, F. Dynamic calculation of an innovative device for reducing reaction torque, Calculus 2024, Vol. 12(11) 219.

[192] Timofte, S.; Miclosina, C.O.; Cojocaru, V.; Gerocs., A; Korka Z.I. Inertial propulsion of a mobile platform driven by two eccentric bodies, -Applied Sciences, 2023, vol. 13 (17), 9511

[193] Timofte, S.; Korka, Z.I.; Gerocs, A.; Wisznovszky, S.; Sfetcu, C.R. Kinematic and dynamic investigation of a new inertial propulsion unit. Presented at the International Conference on Science, Technology, Engineering And Economy (ICOSTEE 2022), 24 March 2022, Szeged, Hungary and published in Analecta Technica Szegedinensia, 2022, Vol. 16(1), p. 27-32.

[194] Timofte, S.; Cindea, L.; Hațiegan, C. Robot for tracking rectilinear motion, Studia Universitas Engineering, 2022, Vol. 67 (1), p. 246-255.

[195] Timofte, S.; Cindea, L.; Design and testing of a mini robot for tracking a welding technology path, Robotics & Management, 2021, Vol. 26(1), p. 17-21.

[196] Timofte, S.; Cindea, L.; Hațiegan, C. Controlling a vehicle through a smartphone application, Annals of the "Constantin Brâncuși" University of Târgu Jiu, Engineering Series, 2021, Vol. 2, pag. 39-43.