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MECANUM WHEELED PLATFORMS FOR SPECIAL APPLICATIONS

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Abstract: *This paper presents a literature review and perspectives regarding the utilization of Mecanum wheels as running systems for platforms and robots designed for diverse special applications. A mobile platform equipped with four or more Mecanum wheels has the capability of moving with fast reactions in any direction without needing a special steering system having so the property of being omnidirectional. Therefore, one of the greatest advantages of such vehicles is to be highly maneuverable which makes them suitable fortight environments such as industrial plants or warehouses where they are usually implemented as autonomous guided vehicles. However, the utilization of Mecanum wheels as part of running systems for different types of platforms is and will be more and more applicable for special applications in domains such as military, medical, civil engineering, or even space exploration. This paper aims to highlight the applicability of Mecanum wheels in special domains based on the advantages and disadvantages of such running systems.*

Keywords: Mecanum wheel, omnidirectional platforms, specialized robots, structural analysis

1. Introduction

In the last decade, the utilization of robots and autonomous or unmanned vehicles has gained a great expansion in a multitude of domains. Whether we are talking about terrestrial, air, or aquatic traveling environment, progress in the field of autonomous or remote-controlled equipment is obvious and continuously updating and improving.

Regarding the design and manufacturing of mobile terrestrial platforms, there is currently a wide range of options regarding the running system that can be implemented. Here the following can be mentioned:

- wheels;
- tracks;
- screws;
- air-cushion.

Of course, more complex robots or mobile platforms can be realized by combining such subsystems depending on the specific application that are designed for and the characteristics of the running surface that they are traveling on. However, wheeled autonomous or remote-controlled vehicles/ robots are the most widely used.

If we move further and try to find a category of wheels that could be the most suitable for different types of platforms intended to be built, a wide range of available solutions can be implemented, from which the following can be mentioned hereinafter:

- conventional wheels;
- ball wheels;
- omniwheels;
- Mecanum wheels;
- Tri-star wheels.

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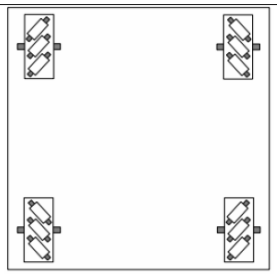
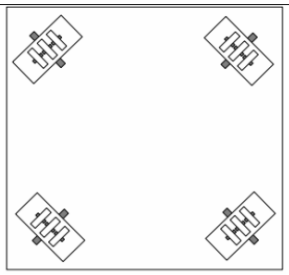
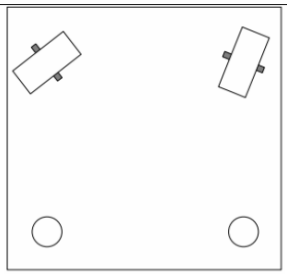
2. Comparison between some types of wheels used for mobile platforms/robots

A detailed comparative analysis between Mecanum, holonomic and swerve drives has been performed in [1] and [2] and the synthetic presentation of advantages and disadvantages for each type of running system is reminded in Table 1.

Table 1 Comparison between different types of drive [1]

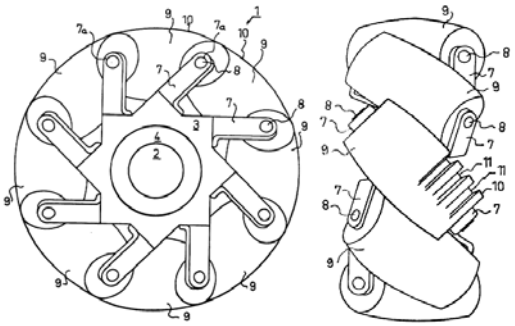
	Mecanum drive	Holonomic drive	Swerve drive
Description	 Wheels with angled rollers	 Wheels with "straight" rollers (omniwheels)	 Independently steered drive modules
Advantages	- compact design - high load capacity - simple to control - less speed and pushing force when moving diagonally	- low weight - compact design - simple to control - less speed and pushing force when moving diagonally	- simple conceptually - simple wheels - continuous wheel contact - high load capacity - robust to floor conditions
Disadvantages	- very complex conceptually - discontinuous wheel contact - high sensitivity to floor irregularities - complex wheel design	- more complex conceptually - discontinuous wheel contact or variable drive-radius - sensitive to floor irregularities - lower traction	- complex mechanical design - heavy and massive design - complex to program and control - high friction and scrubbing while steering

The focus of the paper will remain further on Mecanum wheels due to their advantages in terms of mobility and maneuverability.

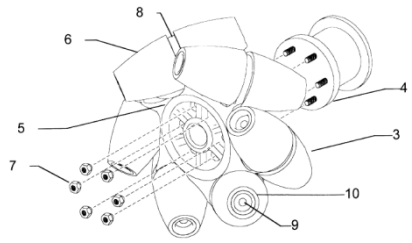
3. Particularities of Mecanum wheeled platforms

3.1. Mecanum wheel design insights

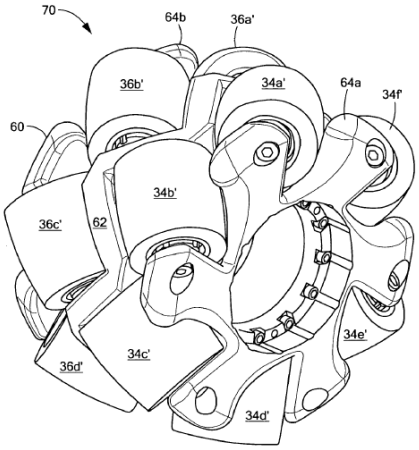
Bengt Ilon, an engineer employed at the Swedish company Mecanum AB, was the one who designed and invented the Mecanum wheel in 1975. The approved patent [3] consists of a central wheel with eight rollers disposed on eight supports, which are bonded to the central wheel, through eight bolts. The conventional Mecanum wheel has the rollers inclined at 45^{o}, representing the angle between the axis of the central wheel and the axis of each roller disposed at its periphery. As seen from the lateral, the contour of the Mecanum wheel tends to have a circular shape resulting from the position and geometry of the rollers. Most significant designs of Mecanum wheel that have been patented since 1975 are visually and chronologically presented in Figure 1.



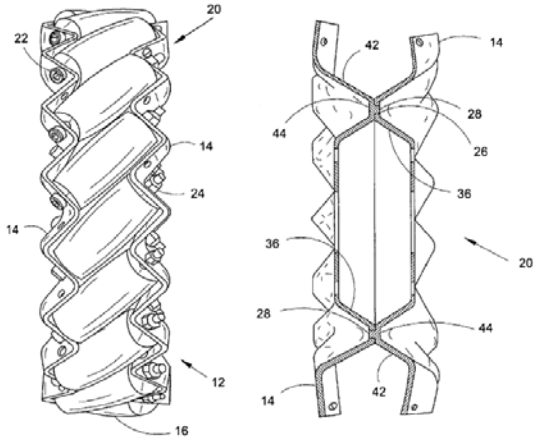
a) Patent no. 1 –Ilon, 1975 [3]



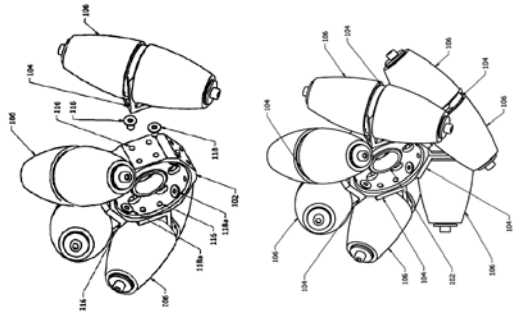
b) Patent no. 2 – Barnett (Airtrax), 2002 [4]



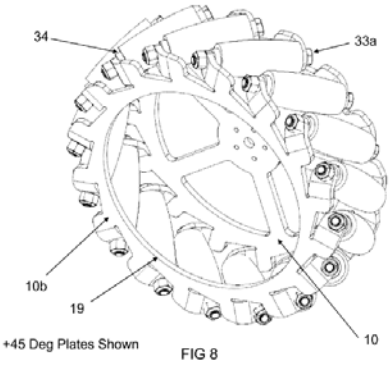
c) Patent no. 3 – Potter, 2010 [5]



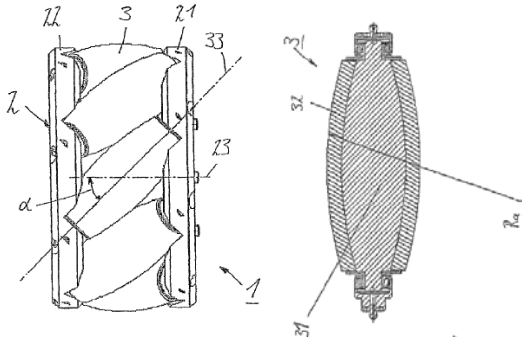
d) Patent no. 4 – Baker, 2010 [6]



e) Patent no. 5 – Scogna, 2011 [7]



f) Patent no. 6 – Schlee, 2013 [8]



g) Patent no. 7 – Günther (KUKA) – 2014 [9]

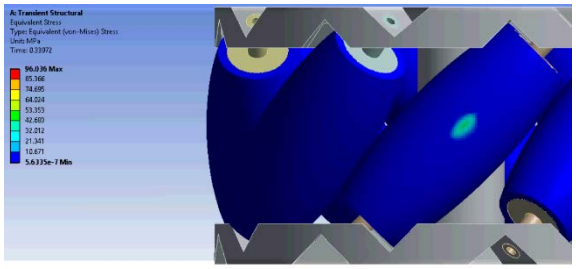
Figure 1: a) ÷ g) Significative patented Mecanum wheel designs

By visually analyzing the main sketches of the seven patents previously presented it can be noticed that the wheels may have various configurations in terms of rim design and rollers number, geometry, or fitting method. On the other hand, by studying in detail the content of the patents, it can be remarked that the tendency is to find solutions to a series of issues related to the Mecanum wheels such as:

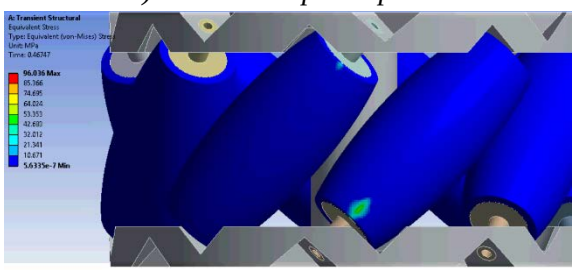
- self-induced vibrations;
- premature rollers wear;
- high complexity of the design;
- high complexity of mounting and dismounting of the components.

As mentioned before, even if the contour of the Mecanum wheel tends to be circular, when rolling self-induced vibrations occur due to the discontinuous contact between the wheel and the running surface. On the other hand, due to high friction between the rollers and the ground during travelling in diverse directions, the rollers need periodical replacement as geometrical differences from one wheel to another onto the same platform is translated into errors in following the right path of travelling. For

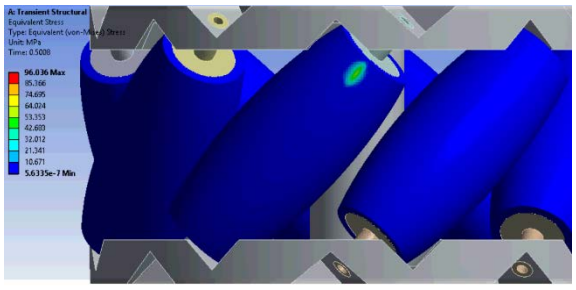
these reasons and corroborated with the appearance of new materials (such as diverse derivatives of rubber, polyurethane, or acrylic thermoplastic) that can be suitable for this kind of application and with the new manufacturing technologies that are currently available, lately, there is a raising interest on designing new configurations of Mecanum wheels.
Moreover, having available new and complex software tools for structural analysis of the components of a Mecanum wheel or of an entire platform equipped with such a running system, a growing concern over the improvement of the contact between the wheel and the running surface can be noticed in the last decade, based on these updated modelling and simulation programs [2], [10].
Related to this topic our research has provided good results, with various simulations being performed in ANSYS software both in static and transient regimes.



a) Contact ellipse in position 1



b) Contact ellipse in position 2



c) Contact ellipse in position 3

Figure 2: a)÷c) Captures from ANSYS Workbench showing the contact ellipse in successive positions when rolling

Studies have been conducted based on a 3D modelled Mecanum wheel Nexus code Nex-NM203A (diameter – 203mm, width – 103 mm, number of rollers – 8, weight of the wheel – 8 kg, maximum load on the wheel – 250 kg). Analyses have been performed in ANSYS Workbench (see Figure 2) by using the Finite Element Method (FEM) and are mainly referring to:

- the study of the influence of the roller's curvature on the way of variation of the contact ellipse between the Mecanum wheel and the running surface;
- the study of the influence of the hollowness variation of the rollers onto de elliptic Hertzian contact.

Related to our research, the novelty consists of 3D modelling of the Mecanum wheel in the same software environment that allows performing structural analysis, in this case, ANSYS program. Therefore, a big advantage is represented by the possibility of parameterizing the model and running multiple simulations with a good level of automatization.

3.2. Constructive solutions used on Mecanum wheeled platforms/robots

The running systems of the Mecanum wheeled platforms or robots can have multiple configurations depending on the destination of the products. In this context two, three, four or even more Mecanum wheels can be used to equip such vehicles, but the most common constructive solution is based on four wheels, disposed as illustrated in Figure 3.

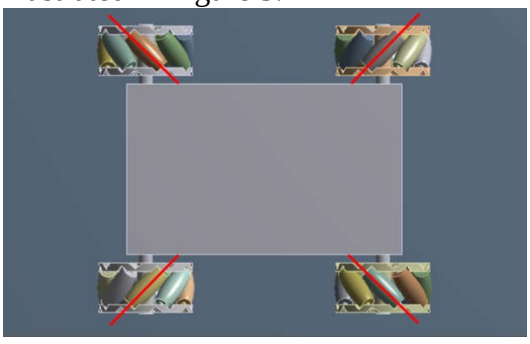


Figure 3: Mecanum wheels positioning on a 4 wheeled platform – top view

By positioning the wheels accordingly, the platform can perform movements in an infinity of directions only by changing the angular speed from 0 to the maximum available and by choosing the appropriate sense of rotation (see Figure 4).

Figure 4: Some particular traveling directions depending on the sense/intensity of rotation of the Mecanum wheels

One of the most known producers of Mecanum wheeled vehicles is KUKA company from Germany, which can deliver platforms based on four, eight, twelve, or twenty-four wheels, managing to offer a wide range of solutions in terms of maximum payload – from 3 to 90 tones. The heavy-duty variant, equipped with 24 Mecanum wheels (see Figure 5), can reach a total length of 30 meters [18].

Figure 5: KUKA omniMove XXL [18]

4. Utilization of Mecanum wheeled platforms in special applications

4.1. Industrial applications – main field

As resulting from [1], [2], [10] and [17], the main domain in which the Mecanum wheel knows the highest popularity is the industry. Whether we discuss about automotive, aeronautics, or other industries, the applicability of omnidirectional robots and platforms is relevant for moving, either autonomously or remote-controlled, materials, components, subsystems, or even entire assemblies/vehicles/airplanes. The main functionalities are in close connection with logistics consisting of specific operations such as lifting, moving, precise positioning, or depositing goodsat the ground level or on shelves.

4.2. Military field

Even if most of the military terrestrial activities are conducted in outdoor operations often on deformable or rough terrain and the Mecanum wheels are considered to be applicable mainly indoors and only on flat surfaces, some particular applications might be found for such equipped robots or platforms. On one hand, Robotics and UGVs are domains that gain more and more interest in relation to the military field in the last period, therefore solutions for diversity in terms of running systems are permanently looked for [11], [15] and [17]. On the other hand, several applications in an indoor environment and on flat paved surfaces can also be identified even in the military domain. Given the fact that this field was not sufficiently explored in the context described in this article, several potential future applications where the Mecanum wheeled platforms/robots can be used by the armies in various sectors of activity are summarised in Table 2.

Table 2 Applicability of Mecanum wheeled platforms/robots in military field

Product/application	Sector	Control method	Environment	Running surface
Armed platform	Combat	RC	Indoor/outdoor	Flat/rough
EOD robot	CS	RC	Indoor/outdoor	Flat/rough
Reconnaissance robot	CS	RC	Indoor/outdoor	Flat/rough
NBCreconnaissance robot	CS	RC	Outdoor	Flat/rough
Dummy tanks mover	CS	RC	Outdoor	Flat/rough
Targets support trolley	Training	RC	Outdoor	Flat/rough

Forklift	Logistics	RC/manned/ autonomous	Indoor/outdoor	Flat
AGV	Logistics	Autonomous	Indoor	Flat

CS – combat support, RC – remote-controlled, AGV – autonomous guided vehicle

4.3. Medical field

Mecanum wheels have already been employed in the medical field especially as running system for wheelchairs, several examples being detailed in [1].

Given the fact that logistics also represent an important sector of medical environment, applicability of Mecanum wheel can be identified for AGVs to be used in pharmaceutical warehouses to manipulate medicines, or with cleaning and disinfecting purposes.

The COVID-19 pandemics also contributed to the raising interest in using robotics and automatization in the medical domain. Lately, there was a great concern in finding solutions for medicines/food/water delivery to patients sheltered in quarantined areas from the hospitals with minimum interaction between medical personnel and infested individuals. Thereby, Mecanum wheeled remote-controlled robots could be a good solution for this type of operation.

4.4. Civil engineering field

The field of construction is a sector in which robotics can be widely applied. Whether we are talking about the construction of residential buildings, office buildings, industrial halls, factories, schools, or hospitals, or we are talking about the construction or maintenance of road infrastructure, mobile platforms can find their applicability.

Moreover, the Mecanum wheels might be a good solution for this kind of vehicle, given their high mobility and manoeuvrability, especially on horizontal flat surfaces. Some interesting applications of Mecanum wheeled platforms that could be an interesting subject for future projects in the civil engineering sector have to be mentioned hereby:

- RC (remote-controlled) mobile platform for the application of road markings;
- RC mobile platform for the maintenance of the green sidewalk;
- RC robot for highway maintenance or cleaning;
- RC robot equipped with optical/LASER devices used for cadastral measurements;
- RC/autonomous mobile platform used for manipulating heavy loads;
- AGV used in 3D printing of modern buildings.

4.5. Space exploration field

When talking about space exploration, obviously NASA (National Aeronautics and Space Administration Agency) represents the reference in this domain. According to [1], NASA conducted a project which followed the development of a Mecanum wheeled robot for hazardous environment exploration (see Figure 6).

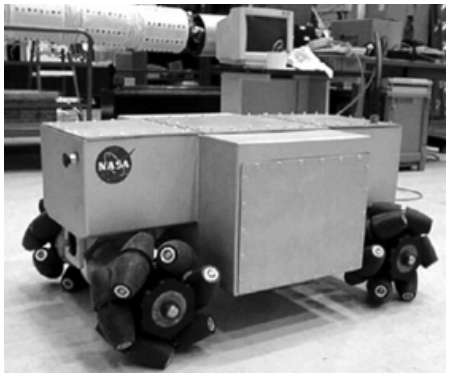


Figure 6: NASA OmniBot mobile base [1]

In [12] is presented a rare but relevant research on the performances of the Mecanum wheels on deformable terrain, in comparison with a conventional plain wheel, both having the same diameter and being manufactured from the same materials. The work also presents several tests with a four Mecanum wheels robot

that were performed in deformable terrain and on inclined surfaces resulting in relevant practical conclusions. The study is part of a more comprehensive project aimed to develop a planetary rover equipped with Mecanum wheels (see Figure 7).

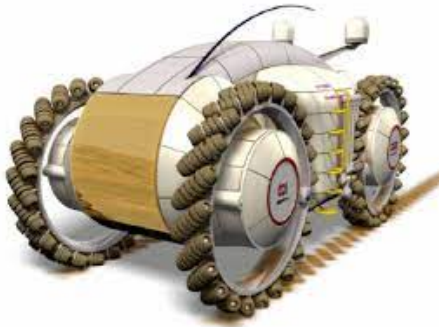


Figure 7: MarsCruiserOne [12]

Due to their limitations when travelling on deformable or rough/rocky/sandy terrains Mecanum wheels are though not the most appropriate solution for space exploration activities, as mentioned in [14], especially when carrying certain loads on the platform. However, this domain remains open for further research as new materials are being constantly developed and recent advanced technologies could conduct to improve performances not only on flat surfaces.

Also, regarding the interaction between a wheel and the running surface new solutions have been recently investigated and good results were obtained. Therefore, the method described in [16] could be adapted for studying the Mecanum wheel - ground interaction based on image processing in Matlab software.

5. Conclusions

The paper represents a short survey of the applicability of Mecanum wheels as a running system for different types of mobile platforms or robots, highlighting fields that are notmuch explored related to this technology. Given the advantages and disadvantages of the Mecanum wheels, which are briefly described in the current article, domains, where this specific concept of wheels could be suitable, were hereby investigated.

Besides the applications that were already presented, also multidomain applicability can be mentioned for platforms equipped with Mecanum wheels, whether autonomously guided or remote-controlled, such as:

- lawn mower robot;
- cleaning smart robot;
- ground painting/marking robot (playing surface for different sports, parking lots, airports);
- surveillance robot (border police, security agencies);
- educational robots or mobile platforms;
- robots and toy cars.

Knowing the limitations of the Mecanum wheels generated by discontinuous contact, self-induced vibrations, and high frictional behaviour in rolling, on one hand, and having available modern and powerful software programs that facilitate the design of such running system, on the other hand, obviously that this domain will gain more and more interest in order to find appropriate and efficient solutions to optimize the contact of the Mecanum wheels with the running surface.

To conclude, this domain remains open for further research also because new materials are being constantly developed and recent advanced on manufacturing technologies could conduct to improve the performances of the Mecanum wheels not only on flat surfaces.

References List

[1] Adăscăliței F., Doroftei I. Practical Applications for Mobile Robots based on Mecanum Wheels - a Systematic Survey, Proceedings of International Conference On Innovations, Recent Trends And Challenges In Mechatronics, Mechanical Engineering And New High-Tech Products Development – MECAHITECH'11, vol. 3, 2011.

[2] Giurgiu T., Puică C., Pupăză C., Nicolescu F.A., Zapciu M. Mecanum wheel modeling for studying roller-ground contact issues, Buletinul științific al Universității „Politehnica" din București, Series D, Vol. 79, Iss. 2, 2017, pp. 147-158.
[3] Ilon B. Patent no. 3,876,255/08.04.1975 - WHEELS FOR A COURSE STABLE SELF PROPELLING VEHICLE MOVABLE IN ANY DESIRED DIRECTION ON THE GROUND OR SOME OTHER BASE.
[4] Barnett-Harris D. Patent no. US 6,340,065 B1/22.01.2002 - LOW VIBRATION OMNI-DIRECTIONAL WHEEL.
[5] Potter S. D. Patent no. US 2010/0187779 A1/29.07.2010 - OMNI-DIRECTIONAL WHEEL.
[6] Baker A. R. Patent no. US 7,641,288 B1/05.01.2010 - OMNI-DIRECTIONAL WHEEL DESIGN FOR CONSTRUCTION COST REDUCTION.
[7] Scogna J. Patent no. US 8,011,735 B2/06.09.2011, WHEEL FOR OMNI-DIRECTIONAL VEHICLE.
[8] Schlee K.L. (HELICAL ROBOTICS), Patent no. US 2013/0292918 A1/07.11.2013, MECANUM WHEEL.
[9] Günther W. (KUKA Laboratories GmbH), Patent no. US 8,833,862 B2/16.09.2014, WHEEL.
[10] Ming-Hsun Ying and Chih-Hung G. Li, Optimization of Mecanum Wheels for Mitigation of AGV Vibration, Proceedings of International Conference on Advanced Robotics and Intelligent Systems and National Conference on Advanced Robotics (ARIS & NCAR 2021).
[11] Coroiu A., Petrişor S. Aspects Regarding the Design, Practical Realization and Implementation of a Functional Prototype of Wheeled Minirobot for Engineering Reconnaissance. International conference KNOWLEDGE-BASED ORGANIZATION. 2021, 27 (3) pg. 15-20, https://doi.org/10.2478/kbo-2021-0083.
[12] Ransom S., Krömer O., Lückemeier M. Planetary rovers with Mecanum wheels, 16th ISTVS Intl Conf, Nov 25-28, 2008, Torino, Italy.
[13] Petrișor S.M., Bârsan G., Simion M., Virca I., Moșteanu D.E. Brevet de Invenție nr. 132301/2022, Robot pe șenile destinat operațiilor de deminare umanitară.
[14] Shao Junpeng, He Tianhua, Jiang Jingang and Zhang Yongde, Recent Patents on Omni-Directional Wheel Applied on Wheeled Mobile Robot, Recent Patents on Mechanical Engineering 2016, Vol. 9, iss. 3, pp. 215 – 221.
[15] Petrişor S.M., Bârsan G. and Moşteanu D.E. Aspects on the design of a tracked mini robot destined for military engineering applications. Romanian Journal of Technical Sciences −Applied Mechanics, 2017, 62(1), pp. 40−46.
[16] Roșca P., Mărmureanu M.I., Țigănescu T.V., Pîrvulescu C.M, Bîndac I.M., Doru C. Determination of tyre-ground interaction parameters through image processing in Matlab, International Journal of Heavy Vehicle Systems 2021 28:5, 630-649.
[17] Petrişor S.M., Bârsan G. Aspects on the design, implementation, and simulation of a tracked mini robot destined for special applications in theatres of operations, Proc. SPIE 9067, Sixth International Conference on Machine Vision (ICMV 2013), vol. 9067.
[18] ***https://www.kuka.com/en-de/products/mobility/mobile-platforms/kuka-omnimove, accessed on 23rd of May 2022.