TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 64, Issue III, September, 2021

EXAMPLE OF GOOD PRACTICES REGARDING THE ORGANOLOGICAL CONSTRUCTION OF A ROBOTIZED TECHNOLOGICAL PRODUCT FOR HUMANITARIAN ENGINEERING OPERATIONS

Silviu Mihai PETRIȘOR, Mihaela SIMION

Abstract: *This paper presents a technological product that is the subject of an invention (patent RO132301 A0/2021) that refers to a tracked robot intended for humanitarian demining missions electrically operated with energy captured from the sun. The following are presented: the description of the technological product, the technical problem that the invention solves, the advantages and the applicability of the patent of invention in the military environment.*
Key words: *advanced military technologies, technological humanism, avant-garde element, engineering operations*

1. INTRODUCTION

The ever-changing military environment must keep up with the current imperatives of responsible intelligence and applied technological humanism, coupled with initiatives to ensure a stable balance between global operational challenges, the protection of the human factor and the concern for the health of the planet (reducing pollution by using innovative renewable energy solutions) [Pet 14].

There are tracked robots currently used in humanitarian demining operations, an example in this sense being the Nemesis HD [Net 01] robot, the RMA tEODor [Net 02] robot, respectively. The disadvantages of these robots consist in the fact that they use fossil fuels for their operation, the operating time is reduced, it is impossible to simultaneously perform the operations of detection and demining of unexploded ordnance, increased energy consumption, complicated constructions, big dimensions, low flexibility, and by their use less attention is paid to modular interchangeability [Isp 04] and, implicitly, to the possibility of carrying out, in a timely manner, several operations specific to humanitarian demining.

2. PRESENTATION OF THE TECHNOLOGICAL PRODUCT

The invention refers to a tracked robot intended for humanitarian demining operations, pertaining to the technical field — advanced military technologies and is part of the category of mobile tracked robots that are able to replace the human factor (as a vanguard element) in areas that present a high risk for his health and life, either by avoiding accidental detonation or by detecting and demining anti-personnel anti-armour minefields in countries where military conflicts have taken place in order to restore them to the economic and social circuit according to United Nations (UN) standards [Gal 15].

2.1 The technical problem that is solved

The documentary research on the technological product, carried out and based on patents RO129442 A0/2021 [Pet 21] and RO128494 B1/2016 [Pet 16], respectively, has highlighted the fact that the technical problem

Received: 15.07.21; **Similarities**: 09.08.21: **Reviewed**: 02.09.21: **Accepted**:15.06.21.

solved by the invention (the increase in actional flexibility by simultaneously carrying out several operations specific to humanitarian demining, corroborated with the increase in the accuracy of grabbing and of handling-storing of mines cleared from the field) and the removal of the disadvantages listed above can be materialized by taking into account the fact that the robot is capable of detecting and demining, at the same time, the antipersonnel and the anti-armour mines in the minefields, by means of high-performance detection equipment (video, audio and radio control), mounted on the mechanical structure of a translation system consisting in the following elements: screw-nut-guide elements, attached to the front area of the tracked base and electrically operated by means of step-by-step electric motors. The innovative organological and functional characteristics possessed by the robot contribute significantly to the solving of the technical problem that the robot can solve, it can move autonomously, electrically operated by means of electric motors that take the energy from photovoltaic cells encapsulated in solar panels, the technological product is also provided with a container for storing the explosives necessary for humanitarian demining and has a fully modularized mechanical structure, with independent functioning, compact and easy to maintain, it uses in its structure materials and components resistant to hazardous environments.

2.2 The constructive and functional solution of the tracked robot

The following is an example of a practical realization of the technological product of the tracked robot-type, according to the invention, having in view Figures 1… 9.

The tracked robot, according to the invention, is composed of two main organological structures: the tracked base and the serial-modular robot of the TRTTR type (3 Translations and 2 Rotations) (Fig. 1, Fig. 2), to which the translation system of the S.Tr.+S.Dm device for detecting unexploded ordnance is added. The tracked robot in modular construction (Fig. 1, Fig. 2, Fig. 3 a, b, c), according to the invention, consists of four independent modules: the basic translation module, the rotating module, the vertical arm and the horizontal arm.

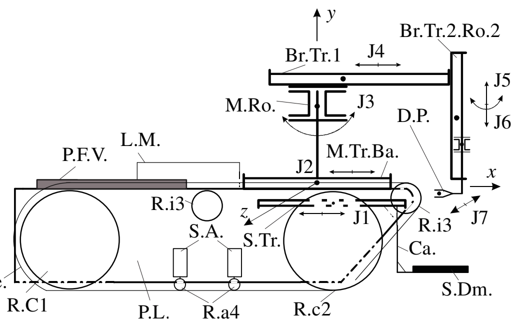

Fig. 1. Structural kinematic diagram of the tracked robot

Each module and/or arm has at least one degree of freedom, except for the vertical arm that has two degrees of freedom (a vertical translation and a rotation along the y-axis).

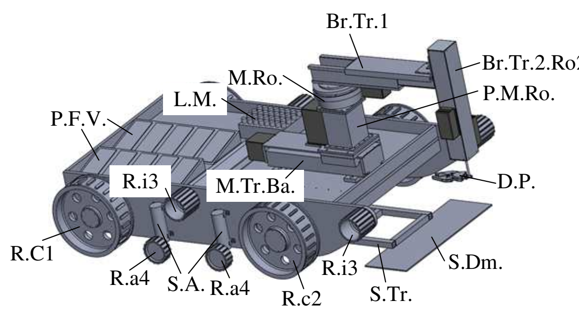

Fig. 2. The triorthogonal model of the tracked robot

Thus, an architectural modular-serial open chain configuration of robot that possesses in the structure of the kinematic chain 5 degrees of freedom (TRTTR) given by each module is obtained, to which the plane-parallel translation movement of the DP clamping device is added, which corresponds to the tightening movement in the xOz plane and the horizontal translation movement (along the x-axis, Fig. 1) of the translation system of the S.Tr., S.Dm mine detecting device.

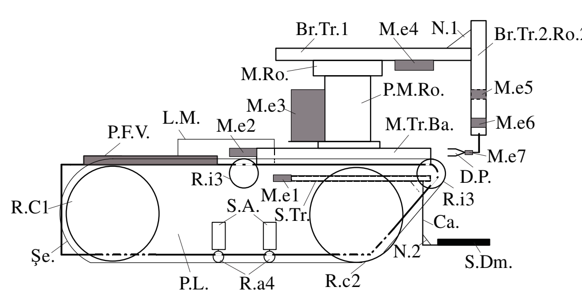

Fig. 3a

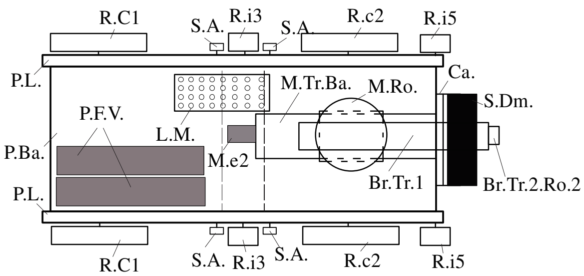

Fig. 3b. The general structure of the tracked robot: **a** – side view, **b** – view from above, **c** – view from below

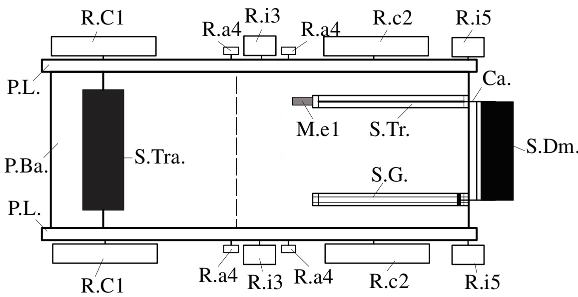

Fig. 3c

The design program used to make the triorthogonal model of the tracked robot (Fig. 4), allowed for the definition of the material used in the organological construction of each and every module (carbon steels and steel alloys, aluminum alloys and bronze alloys), at the same time highlighting the characteristics related to the type of material, such as: density, elasticity modulus, Poisson's ratio, yield strength, etc. [Bej 09] Thus, having the materials for each organological component defined, the program was able to determine the gross weight of the tracked robot as being 425 kg before its practical execution.

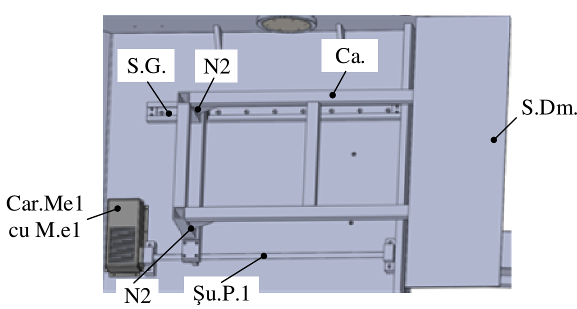

Fig. 4. The triorthogonal model with the components of the S.Tr. translation system

The tracked base (Fig. 1, Fig. 2, Fig. 3a, b, c, Fig. 4) consists of the following elements: the resistance structure, formed by the P.Ba base plate and two P.L side plates, both made of high-strength steel sheets, with a thickness of 15 mm and 20 mm, respectively; the R.C1 driving wheels; the R.c2 driven wheels; the R.i3 intermediate wheels; the S.A. damping systems with the R.a4 damping wheels; the S.Tra transmission system, which is mounted in the back area of the tracked robot and which ensures the transmission of the movement from the transmission elements to the R.C1 driving wheels; the S.Tr translation system of the S.Dm mine detection device, consisting of the Șu.P.1 screw-nut actuation system, the S.G. guide system, the metal frame made of Ca. thin-walled square pipes and the N2 resistance ribs; the P.F.V photovoltaic panels; the L.M. container for storing the explosive and the tracks that help the robot move. The tracked base performs the forward-retraction movement by means of the R.C1 driving wheels, of the R.c2 driven wheels and of the R.i3 intermediate wheels, together with the Şe track, which wraps the wheels enumerated above. Due to the shape of the P.L. side plates, due to the geometry of the R.C1 driving wheels and of the R.c2 driven wheels, the tracked robot can move on flat or inclined surfaces (with inclination < 50^0), with or without obstacles (with an obstacle height < 50 cm). The S.Tra transmission system that engages the two R.C1 driving wheels is mounted in the area behind the tracked base, leading to a stronger traction. The S.A. damping system, consisting of a mechanical piston-compression spring mechanism, together with the R.a4 wheels has the role of maintaining the Şe tracks in a stretched state and to facilitate the passage over obstacles, respectively. The turning movement of the tracked robot is obtained by braking one of the R.C1 driving wheels. Two or more P.F.V photovoltaic panels are mounted on the tracked base and these have the role of powering, during the day as well as during the night, the electric actuating motors, corresponding to each module of the robot and of the translation system of the device for detecting unexploded ordnance (Fig. 3a, b, c).

The S.Tr translation system (Fig. 4) of the S.Dm mine detection device is composed of a Șu.P.1 screw-ball nut drive system and an S.G.

guide system and possesses a degree of freedom - translation in the horizontal direction and it also performs the forward-retraction movement on the x-axis direction. The translation movement is performed by means of the ball nut, the drive of the screw being generated by means of the M.e1 electric motor. The S.Dm unexploded ordnance detection system is mounted on a Ca. metal frame made of thin-walled pipes, which are fixed by means of the screws to the ball nut and to the S.G. guide system. The S.Tr translation system will be in the maximum advance position when the robot is positioned in the advance movement in order to detect unexploded ordnance and in the maximum retraction position, respectively, when the demining mechanism is positioned by means of the serial-modular robot of the TRTTR type, the maximum advance position of the translation system having a length of 620 mm, according to Figure 9. The rotation movement transmitted from the M.e1 electric motor to the rotating shaft is achieved by means of a transmission system composed of wheel-belt, the motor being protected from the environment outside by means of a Car.Me1 housing made of thin tin sheet and provided with cooling slots in order to prevent it from overheating during operation. The cooling of the motors is done naturally by the exchange of temperature between the outside air and the air inside the housing heated by the motor during operation.

The serial-modular robot of TRTTR-type consists of: the translation module of the M.Tr.Ba base, the M.Ro rotating module mounted on the P.M.Ro supporting leg by means of the fixing screws, the Br.Tr.1 translation arm mounted in a horizontal position, the Br.Tr.2.Ro.2 translation and rotation arm mounted in a vertical position and the D.P. clamping device. The translation module at the base of the M.Tr.Ba robot and the Br.Tr.1 horizontal translation arm (Fig. 5) are two compact modules, consisting of an actuating system with screw-ball nut mechanism that converts the rotation movement of the screw into translation movement by means of the ball nut.

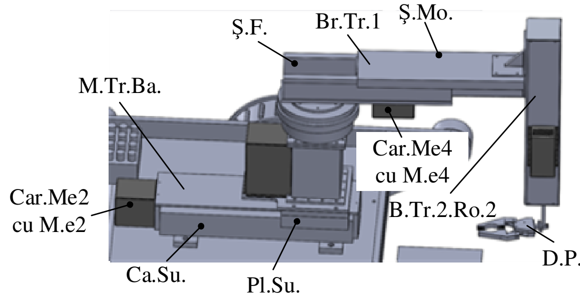

Fig. 5. The triorthogonal model with the components of the Br.Tr.Ba basic translation arm and of the Br.Tr.1 horizontal one

The ball nut performs the translation movement in a horizontal direction, in both senses (forward-retraction), on the surface of this, the Pl.Su support plate of the basic translation module that slides on the Ca.Su support housing of the module and the Ș.Mo mobile rail of the vertical translation arm that slides on the Ș.F fixed tracks, respectively, are mounted. Thus, two degrees of mobility of the robot structure are obtained, namely: the J2 horizontal translation of the entire serial-modular robot and the J4 horizontal translation of the Br.Tr.1 horizontal arm, respectively, together with the translation of the Br.Tr.2. Ro.2 vertical arm and with the D.P clamping device are obtained. The two translation modules, Br.Tr.1 and Br.Tr.2.Ro.2, respectively, are actuated individually by means of the M.e2 and the M.e4 electric motors, these being protected from the external environment by the Car.Me2 and the Car .Me4 housings, made of thin tin and provided with cooling slots for the actuating motors. The rotation movement from the M.e2 and M.e4 electric motors to the rotating shafts is achieved by means of wheel-belt-type transmission systems, the cooling of the motors being done naturally, by the temperature exchange between the external air and the air inside the housings, the latter being heated by the motors during operation.

The M.Ro rotating module (Fig. 6) consists of the following components: the Ar.Ro rotating shaft, the I.Ro rotation ring, the I.F fixed ring, the F.Su support flange, the 1 Ca.1 and 2 Ca.2 cover and the R.Tr.1 transmission wheel, all these being embedded in the housing of the C.M.Ro rotating module.

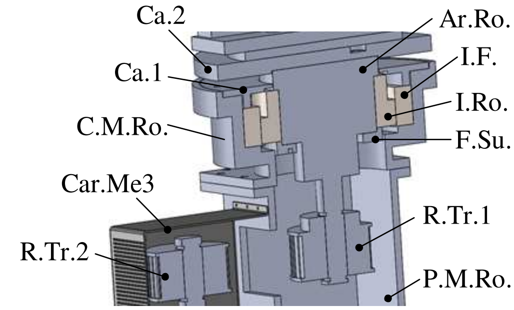

Fig. 6. The triortogonal model with the components of the M.Ro. rotating module

The J3 rotation along the z-axis of the M.Ro rotating module, on which the M.Tr.Ba horizontal translation arm and the vertical Br.Tr.1 arm, respectively, with the D.P. clamping device, is achieved by means of the Ar.Ro rotating shaft - I.Ro rotation ring assembly, fixed by screws to the fixed I.F ring. The movement of the rotating module on the vertical direction is prevented by the I.F. fixed ring, which is supported on the housing of the C.M.Ro rotating module by the F.Su support flange fixed with countersunk screws to the Ar.Ro rotating shaft and to the 1 Ca.1 cover attached to the housing of the C.M.Ro rotating module by means of the countersunk screws. The rotation movement of the rotating module is transmitted from the M.e3 electric actuating motor to the Ar.Ro rotating shaft by means of the R.Tr.1 and R.Tr.2 wheel transmission system - transmission belt. The M.Ro rotating module is mounted on the P.M.Ro supporting leg, the latter being made of thin-walled metal pipe of square cross section and which allows for the rotation of the horizontal and vertical arm in the xOz plane with a maximum angle of 350° (Fig. 9). The rotation movement from the M.e3 electric motor to the rotating shaft is transmitted by means of a wheel-belt transmission system, the actuating motor being protected from the external environment by means of the Car.Me3 housing made of thin tin and provided with cooling slots in order to prevent the overheating of the motor during operation. The cooling of the actuating motors is done naturally as described above.

The Br.Tr.2.Ro2 vertical translation arm (Fig. 7) is mounted, by means of the fixing screws, on the horizontal translation arm, and has in its componence an actuation system with screw-ball nut mechanism, which allows for two degrees of freedom for the assembly: translation on the J5 vertical direction and J6 rotation performed along the z-axis of the screw, on which the D.P clamping device is mounted.

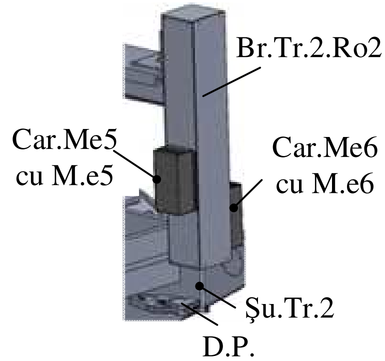

Fig. 7. The triorthogonal model with the components of the Br.Tr.2.Ro.2 vertical translation arm

The two degrees of freedom (the J5 vertical forward-retraction movement and the J6 rotation) are achieved by the Şu.Tr.2 screw by means of the fixed ball nut with, the actuation being generated by the M.e5 and M.e6 electric motors. The rotation movement from the M.e5 and M.e6 electric motors to the rotating shafts is transmitted by means of wheel-belt transmission systems, the motors being protected from the external environment by means of Car.Me5 and Car.Me6 housings made of thin tin and provided with cooling slots. The cooling of the electric motors is done naturally, as presented above. The D.P clamping device (Fig. 8) consists of: the D.Pr clamping fingers, the T.P. flat rods and the body of the C.D.P clamping device, which includes the actuating mechanism with the M.e7 electric actuating motor and the S.F. fixing system of the D.P. clamping device achieved by means of the Şu.Tr.2 screw afferent to the Br.Tr.2.Ro2 vertical translation arm.

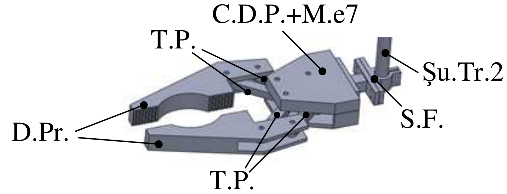

Fig. 8. The triorthogonal model with the components of the D.P. clamping device

The D.Pr clamping fingers are constructed in such a way so that they are interchangeable, which ensures the handling of parts with diverse geometry. In the present scientific demarche, the fingers were designed according to the type of explosive that is used, in order to manipulate their parallelepipedic or circular section and having a diameter between 80 mm and 150 mm and the weight between 0.075 kg and 0.5 kg. The four T.P. flat rods form a parallel plane mechanism, by means of which a J7 plane-parallel translation afferent to the handling fingers is obtained.

All the degrees of movement of the tracked robot, of the translation system, and of the tracked base, respectively, can operate simultaneously and/or independently, the control of the movements of each degree of mobility (linear or angular movement) being ensured by means of the incremental transducers mounted on the axes of each electric actuating motor in the structure of the technological product.

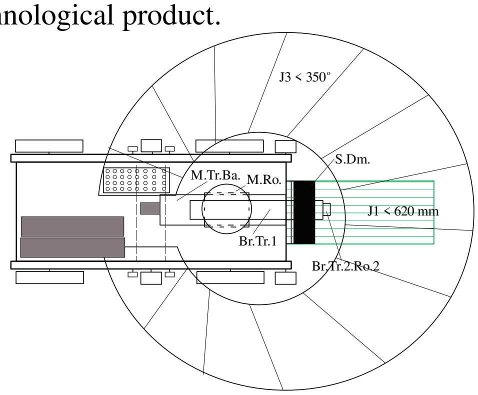

Fig. 9. The working space defined by the J3 kinematic axis of the M.Ro. rotation module and by J1 of the S.Tr. translation system.

The control of the tracked robot and the control of the actuating motors implicitly, which generate the translation and/or rotation movements related to the constituent modules, is performed in open mode, both through wireless networks from operator/equipment to robot and with equipment and programs specific to the action of guidance in the corresponding workspace. According to the invention, a minimum number of 7 axes J1 ÷ J7 can be controlled on the tracked robot, and the linear speed and the maximum rotation speed, respectively, corresponding to each module can vary between 0.5 ÷ 2 m/s and 0.5 ÷ 2 rpm, depending on the operation to be performed.

2.3 The advantages offered by the technological product

According to the invention, the tracked robot offers the following advantages [Pet 20]:

- actional flexibility by mounting in the front area of the tracked base of the robot a translation system composed of screw-nut-guide, which allows for the simultaneous carrying out of humanitarian detecting and demining operations, the mechanical structure of the technological product being provided with a container for storing the explosive necessary for the specified operations;
- modular interchangeability through the possibility of replacing and/or attaching/mounting new translation/rotating modules and horizontal/vertical arms, respectively, so as to obtain various architectures of robotic structures able to cope with the diversified requirements specific to the humanitarian demining operations;
- high flexibility by independent operation with electric motors attached to each module, which allows for high efficiency in functioning and a minimum of energy consumption, obtained by means of a mathematical dynamic-organological calculation algorithm, in order to determine the moment necessary to actuate the kinematic movement torques for each mobile crew in the organological composition of the robot;
- the protection of the human factor, of the organological components and of the communication equipment attached to the robot structures exposed to high-risk humanitarian demining operations;
- the operation of the robot with "green" solar energy represents an economic and ecological solution, contributing, in this way, both to the reduction of the environmental pollution and to the

consolidation of a culture of energy responsibility among the civilian and/or military population.;
- compact and fully modularized architecture, the possibility of operating on rough terrain, easy to maintain and relatively low construction cost;
- easy operation in automatic modes and the programming of movements through learning and manually.

3. CONCLUSIONS

It is worth mentioning the fact according to which the power of a state depends not only on the economic and financial sector, but also on the technological and human acquisitions, on the investments in intelligence and research. The contemporary educational context, based on the four pillars of the knowledge society — education, research, development, innovation —is defined by raising the level of the training standards, by the training opportunities that are offered, by the pragmatic intentionality, by the support of the concepts of *learning by doing*, *learning by enjoying*, *knowledge through scientific research*, respectively. In other words, the replacement of the status of the educable as passive consumer of knowledge with the status of producer of knowledge is aimed at.

The technological product the invention refers to has applicability both in the applicative-military sphere (by improving the actional flexibility within the operations of humanitarian detecting and demining of antipersonnel and anti-armour mines located in dangerous areas, in order to protect the human civilian/military factor and the active organological components in the respective area as well as the protection of the environment), and in the educational sphere (by forming, through military academic studies, highly educated and specialized human resources, meant to face the present diversity of operations and challenges).

4. ACKNOWLEDGEMENTS

This scientific paper is the result of the research activities and of the practical implementation, in the industrial environment, of a 1: 1 scale robotic technological product, of TRL5 type (Technological Maturity Level), activities funded by the research project of the Romanian Ministry of National Defense, position 63/2020-2022, PSCD type, acronym: AVANGARDROBO.

5. REFERENCES

[Bej 09] Bejan M., *Rezistența materialelor*, vol. 1 & 2, Editura Agir, București, 2009 și Editura Mega, Cluj-Napoca, 2009

[Gal 15] Galliott J., *Military Robots – Mapping the moral landscape*, Routledge Tylor & Francis Group, ISBN 978-1472426628, London & New York, 2015

[Isp 04] Ispas V., *Manipulatoare și roboți industriali*, Editura Didactică și pedagogică, R.A., ISBN 973-30-1349-8, București, 2004

[Net 01] http://www.humanitarian-demining.org/2010Design/resources/Nemesis M3_FS-13Feb2017.pdf

[Net 02] http://www.army-technology.com/projects/teodor-explosive-ordnance-eod-robot/ Army-technology Homepage

[Pet 14] Petrișor S.M., Petrișor R.M., *Mecatronica – între imperativele contemporane și paradigma umanisto-tehnologică*, Editura Academiei Forțelor Terestre "Nicolae Bălcescu", ISBN 978-973-153-181-6, Sibiu, 2014

[Pet 16] Petrișor S.M., Bârsan Gh., Ioan D.A.A., *Minirobot pe șenile destinat aplicațiilor speciale în teatrele de operații*, Buletin Oficial de Proprietate Industrială, ISSN 2065-2100, vol. 6, București, 2013

[Pet 20] Petrișor S.M., Simion M., *Aspects regarding the elaboration of the geometric, kinematic and organological study of a robotic technological product "Humanitarian PetSim Robot" used as an avant-garde element of the human factor in high risk areas*, In: Arai K., Kapoor S., Bhatia R. (eds.) Intelligent Systems and

Applications. IntelliSys 2020. Advances in Intelligent Systems and Computing, 1250, Springer, Cham (https://doi.org/10.1007/978-3-030-55180-3_24)

[Pet 21] Petrişor S.M., Grigoraş C.I., Bârsan Gh., Moșteanu D.E., *Minirobot şenilat, destinat aplicaţiilor genistice*, Buletin Oficial de Proprietate Industrială, ISSN 2065-2100, vol. 5, București, 2014

EXEMPLU DE BUNE PRACTICI PRIVIND CONSTRUCȚIA ORGANOLOGICĂ A UNUI PRODUS TEHNOLOGIC ROBOTIZAT DESTINAT OPERAȚIILOR GENISTICE UMANITARE

Rezumat: *În lucrarea de față este prezentat un produs tehnologic care face obiectul unei invenții (brevet RO132301 A0/2021) ce se referă la un robot pe șenile destinat misiunilor de deminare umanitară acționat electric cu energie obținută prin captare de la soare. Sunt prezentate: descrierea produsului tehnologic, problema tehnică pe care o rezolvă invenția, avantajele și aplicabilitatea brevetului de invenție în mediul militar*

Silviu Mihai PETRIȘOR, Ph.D, Eng, Associate Professor, “Nicolae Bălcescu” Land Forces Academy, Technical Science Department, E-mail: robmilcap@gmail.com, No. 3-5, Revoluției Street, 550170, Sibiu

Mihaela SIMION, Ph.D, Eng, Lecturer, Technical University of Cluj-Napoca, Mechanical Engineering Department, E-mail: mihaela.simion@rezi.utcluj.ro, No. 103-105, Muncii Blvd., 400641, Cluj-Napoca