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ASPECTS ON THE DESIGN OF A TRACKED MINI ROBOT DESTINED FOR MILITARY ENGINEERING APPLICATIONS

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Abstract. This paper highlights elements regarding the organological structure and functioning, in a real workspace, of a tracked mini robot structure destined for special applications in theatres of operation, a technological product which is subject to a national patent granted to our institution (Invention Patent no. 128494/ 2016, issues by OSIM Bucharest), the result of research activities undertaken under a contract won by national competition, a grant for young research teams, NP-RH-YR type. The issues outlined in this paper are aspects related to the original invention in comparison with other mini robot structures, the authors presenting succinctly the technological product description, advantages, novelty, originality and its applicability both in the military and applicative area as well as in the educational one.

Key words: tracked mini robot, advanced military technologies, human artificial "partnership", modular structure, engineering applications.

1. INTRODUCTION

In the current military environment physiognomy, the technological humanism imperative is reflected in the implementation of those technological components able to replace the human element in high-risk areas that may affect health or endanger life. For the optimal resolution of these actions it is necessary to have reliable information obtained in real time, under safety conditions; therefore it is recommended that the scout position be held by a tracked mini robot which acts in theatres of operation. But the tracked robots currently used, such as the TALON robot or the tEODor robot, focus on the detection/defusing of unexploded ordnance and less on the level of informational performance.

The functional product proposed in this invention patent, conducted under the above mentioned contract, is characterized as an innovative idea by the production and assembly on the mechanical structure of the mini robot of a modular robotic articulated rotating equipment performing an almost complete rotation movement (355 degrees), which allows the human operator real-time operational field research, removing the inconvenience of the robot's turning in order to have a full view of the terrain, reducing the risk of detection by the enemy in the event of conflict, or increasing capacity to provide timely comprehensive information about the existing risks on terrain harmful to the human operator in peacetime. The designed mini robot has a colour video camera attached in its structure which broadcasts real-time images and information necessary for the processing by the human operator by means of an electronic computer and LEDs in order to have precise framing.

2. THE CONSTRUCTIVE AND FUNCTIONAL SOLUTION OF A TRACKED MINI ROBOT

The present technological product refers to a tracked mini robot with electric actioning and autonomous movement, having four degrees of mobility, a simple mechanical structure, fully modularized and compact, the joining of the constituent modules being performed by means of a rotation joint screwed onto, the reduction the function being achieved by transmission mechanisms within the reducers with dual electric actioning, using in its structure materials and components resistant to hazardous environments. The technological product has applications both in the applicative-military area (by improving the ability to obtain and collect remote video information in order to observe and detect UXO unexploded ordnance and improvised IED devices in places that are dangerous or inaccessible for human operators in theatres of operations) and in the educational field (by improving professional skills/competencies of bachelor, master and doctoral students on the design and assembly of those robotic components designed to contribute to the optimization of the method of obtaining information from areas with harmful effects on humans).

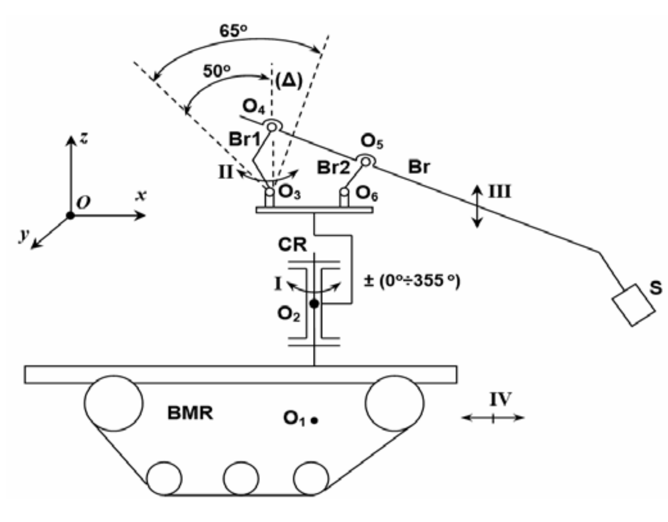
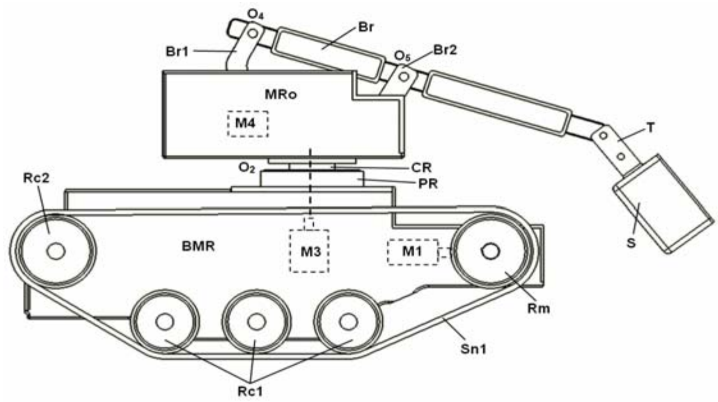
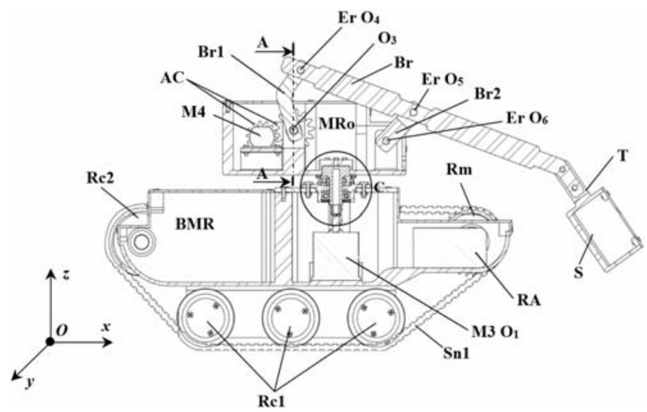


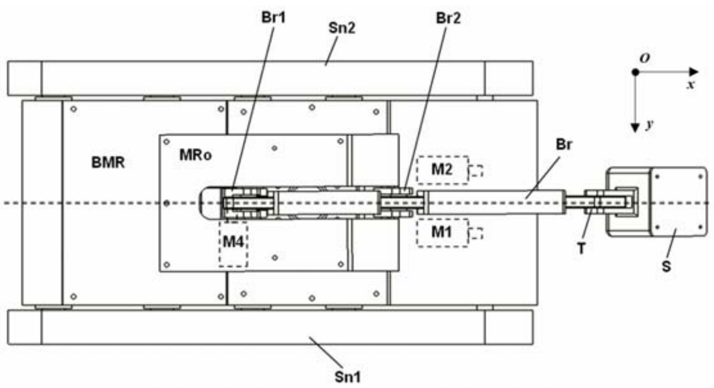
Fig. 1 – The structural kinematic diagram of the designed mini robot.



a)



b)



c)

Fig. 2 – The general structure of the mini robot::
a) lateral view; b) section view; c) top view.

The mini robot under study, whose kinematic diagram is shown in Figure 1, consists of two main modules (a rotation module and a tilting module), each having at least one degree of mobility, to which the BMR base of the mini robot (Fig. 2) is added.

The rotation module MRo (Fig. 2) consists of the following elements: the CR rotation joint having a cylindrical outer surface and the PR rotation plateau. Mounting the CR rotation joint on the BMR base of the mini robot is performed by means of a flat annular part, and by six fastening screws, respectively, whereas the MRo module is positioned and fastened to the CR joint by fastening screws and nuts. The rotation of the CR joint imparted by the M3 motor is obtained within the PR rotation plateau, friction between the two components being eliminated due to the low roughness of the contact surfaces, achieved through a high precision execution. The axial displacement (top-down) of the joint's shaft is stopped by a shoulder provided in the design and the implementation of there.

The tilting module (Fig. 2a) is a quadrilateral mechanism and includes: the Br1 and Br2 forearm, mounted on two support parts (which are common core with the MRo module) by means of the rotating parts and the Br arm, both with compact rectangular exterior surfaces. The tilting movement of the Br arm is provided by the Br1 and Br2 forearms, together with the gear train and the O_4 and O_5 kinematic rotation elements and the M4 electric motor. To the Br arm is attached, by means of the T rod, mount S, used the storage and to protect the room for remote wireless communication, which provides information on areas of interest. The MRo module has two lids, attached to the chassis by means of screws, which allow easy access inside for the human operator, enabling rapid installation and removal of the CR rotation joint, the Br arm and the MRo module on the BMR mount.

The I degree of mobility (Fig. 1, Fig. 3) – the rotation of the MRo module along the *z* axis (made by the CR O_2 rotation couple and ball bearings axial, ball bearings radial respectively) which will also rotate the kinematic chain of the quadrilateral mechanism consisting of the AC O_3 grooved shaft, the forearm Br1, the Er O_4, Er O_5, Er O_6 bolts, the Br2 forearm and of the Br arm – are achieved through an electric stepper motor. The M3 motor positioned vertically in the BMR body, is mounted on the CR joint by means of a feathering shaft assembly, the connection between the shaft of the motor and that of the joint being accomplished by a mechanical coupling. The motor imparts to the CR joint a vertical axis rotation (the Δ axis), the angular velocity having a variable value programmable and controllable by a software preset by the computer from 0° to 355°.

The II and III degrees of mobility (Fig. 1, Fig. 2a, b) – the Br1 forearm rotation and the Br arm tilting – are achieved through an M4 electric stepper motor, which imparts a rotation movement to the Br1 forearm lead element, by means of a bevel gear, which is mounted on the forearm lead shaft. The I and II degrees of mobility can be considered as one from the kinematical point of view, having each of them its technical logic. The motor imparts on the Br arm component, and the Br2 forearm, an oscillatory movement (left-right) by means of the O_3 kinematic element, imparting a tilting movement on the Br arm, tilting movement in a vertical plane, in relation to the (Δ) vertical reference axis as follows: 50° when the Br1 forearm is in a withdrawal position (minimum stroke), and 15° when the Br2 forearm is in an imprest position (maximum stroke). The velocity imparted by tilting is variable, programmable and controllable by means of software, from 15° to 65°.

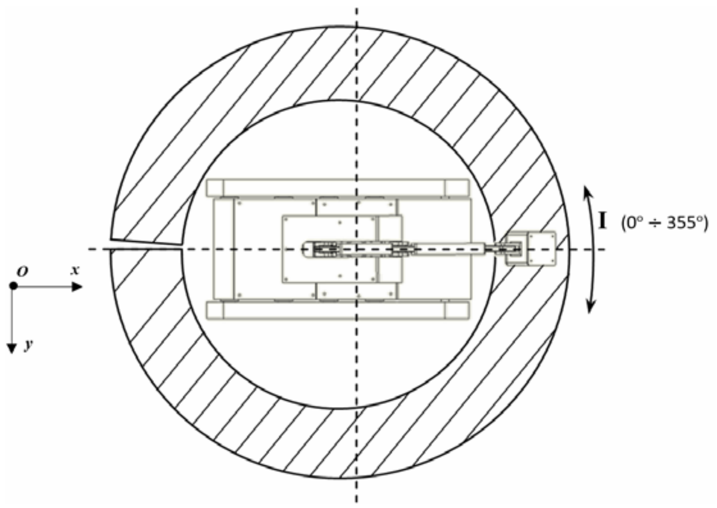


Fig. 3 – Workspace in the maximum positions of the mini robot's Br arm.

The IV and V degrees of mobility (Fig. 1, Fig. 2b) – the mini robot's displacement back and forth and its direction – are provided by the M1 and M2 electric stepper motors mounted in parallel one in relation to the other, whose rotation movement is transmitted, by means of mechanical joints, to a cylindrical gear reducer with double actioning, to the Rm drive wheels pair which, in their turn, set in motion the Rc1 and Rc2 driven wheels, and the Sn1 and Sn2 tracks mounted over the Rm, Rc1 and Rc2 wheels pair. Through the braking of a motor, the Rm wheel corresponding to the clogged motor will stop, only one Rm remaining in gearing, this facilitating the control of the movement direction of the mini robot. The distance of movement is unlimited, the human operator – mini robot communication becoming possible by wireless remote control. The displacement velocity ranges from 0 m/s to 0.5 m/s, taking into account the surface of the investigation terrain, and the velocity of variation of the driving angle ranges between 0 °/min and 360 °/min. The braking of one of the Rm wheels, as well as the driving angles and velocity values, are variable and controllable through software.

The designed tracked mini robot offers the following advantages:

– reduced time for gathering information from theatres of operations by assembling a modular robotic arm on the mechanical structure of the mini robot that can perform a stroke of 355 degrees (almost entirely covering the workspace);

– compact construction, small size, high efficiency, possibility of operation on rough terrain, relatively low construction cost, elimination of the direct intervention of the human factor in dangerous or harmful military conflict zones;

– easy operation in both the automatic, programming movements through learning and manual modes, high efficiency and minimum energy consumption obtained by a dynamic–organological calculation algorithm, shown relation 1, in view to determine the moment necessary for the actuation of the kinematic motion couplings and, implicitly, to choose the appropriate DC motors.

$$[J_{\Delta_1}^{(1)} + J_{\Delta_1}^{(2)}] \cdot \ddot{q}_1 = 9550 \cdot \frac{P_{m_{1\div4}} \cdot \eta_c \cdot \eta_r \cdot \eta_s}{n_{m_{1\div4}}} \cdot i_c \cdot i_s$$

$$\Rightarrow M_{m_{1\div4}} = 9550 \cdot \frac{P_{m_{1\div4}}}{n_{m_{1\div4}}}, \quad M_{m_{1\div4},\,\mathrm{STAS}} = 4.3\,\mathrm{Nm}, \qquad (1)$$

where: $J_{\Delta_1}^{(1)}, J_{\Delta_1}^{(2)}$ stand for the mechanical moments of inertia of the movable system in the MRo rotation module, and of the tilting module in relation to the (Δ_1) rotation axis, ($J_{\Delta_1}^{(1)}$ =0.0223 kg·m^2, $J_{\Delta_1}^{(2)}$ =0.006 kg·m^2) [1]; $\ddot{q}_1$ stands for the output angular acceleration corresponding to the MRo rotation module, $\ddot{q}_1$ =1.5 rad/s^2; 9550 is a factor taken into calculation of the motor torque/moment M_m if the power of the DC motor P_m is calculated in KW and the rotation speed of the DC motor n_m in rot/min; $P_{m_{1\div4}}$ stand for the powers of the DC motors; η_c stand for the output of the cylindrical gear, η_c =0.97 [1]; η_r stand for the output of a pair of bearings, η_r =0.995 [1]; η_s stand for the output of the combined screw, η_s =0.99 [1]; $n_{m_{1\div4}}$ stand for the rotative speeds of the DC motors; i_c, i_s stand for the gear ratios corresponding to the cylindrical gear and the combined screw, i_c =1, i_s =32 [1]; $M_{m_{1\div4}}$ stand for the calculated motor moments used to select standardized motor moments to drive movable system, four motors type A0441BSM90N with an A044/FDH4A10TR-RN20 type encoder embedded in its structure.

All the degrees of mobility of the mini robot can operate simultaneously, and movement control of every degree of mobility is provided by incremental angle encoders mounted on the axes of each electric motor in the mechanical structure of the mini robot. The total mass of mini robot is of 40 kg, and the maximum load it can support is of 2.5 kg. The operating system is made up of 16 commands and the operating modes are automatic, programming of movements by learning and manual.

3. CONCLUSION

With the evolution of military conflicts, development of technique and equipment in the military environment has become obvious, as well. Given that a wide range of requirements must be tackled, including the performance of high –

risk missions, soldiers need, in addition to specialized knowledge and skills, equipment and technology. During the actions that require EOD intervention, danger is around the corner, and soldiers need equipment to ensure their protection. Mini robots, built for various actions (observation, detection, information gathering and rehabilitation), are of vital importance, providing operators, in addition to safety in action, the ability to operate with high precision, without endangering human lives.

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