

THROWABLE TACTICAL ROBOT – DESCRIPTION OF CONSTRUCTION AND PERFORMED TESTS

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Abstract:

This paper concerns a throwable tactical robot (TTR) for special purposes. The necessity of use of that kind of robots and the existing design solutions are discussed. There are also described construction, parameters, and principles of operation of the robot and the control panel, as well as the conducted robot tests.

Keywords: throwable robot, special robot, teleoperation.

1. Introduction

According to increasing rate of terror acts the character and methods of setting up explosive charges has changed. Therefore, there appeared a need to change conception, construction and the scale of pyrotechnic robots and even their tasks. In the last years a bigger emphasis was placed on development of small robots which purpose is not neutralization but acquiring information. Thanks to acquiring significant information, the services are able to react adequately to the incident. The role of small robots is and will be to perform preliminary reconnaissance of incident place, acquiring information for intervention squads in open or secret manner. The other vital attribute of small robots is their independent work as information sources, tracing and simple neutralization machines. The main advantage should be the possibility

to reach every target virtually unnoticeably either in a combat mission or rescue action. Their small sizes should assure secrecy and possibility of free penetration of very small spaces. [1], [2], [5]

2. Throwable robots

The review of existing design solutions shows the most desired direction of development of this kind of robots for active teleobservation and tracing. The main characteristics which small robots should have is the possibility to place them by hand throwing at the operator's interest area. That is in the simplest and fastest way, decreasing the danger to indispensable minimum, allowing to penetrate spaces inaccessible for the operator, i.e. beyond an obstacle. [1], [2]

Nowadays we can find information about different commercial and non-commercial solutions of throwable robots. One of non-commercial robots of this kind is the robot presented in the Figure 1. It consists of two modules connected with each other by a common driven axis. It has also 4 balls (Omni-Ball) positioned at the end of modules that have one active and two passive axes of rotation. Such a solution of the robot construction enables both its moving, in a collapsed form, in narrow areas using balls drive, and moving, for instance, in debris area using then additionally the drive providing the mutual rotation of two modules. [3]

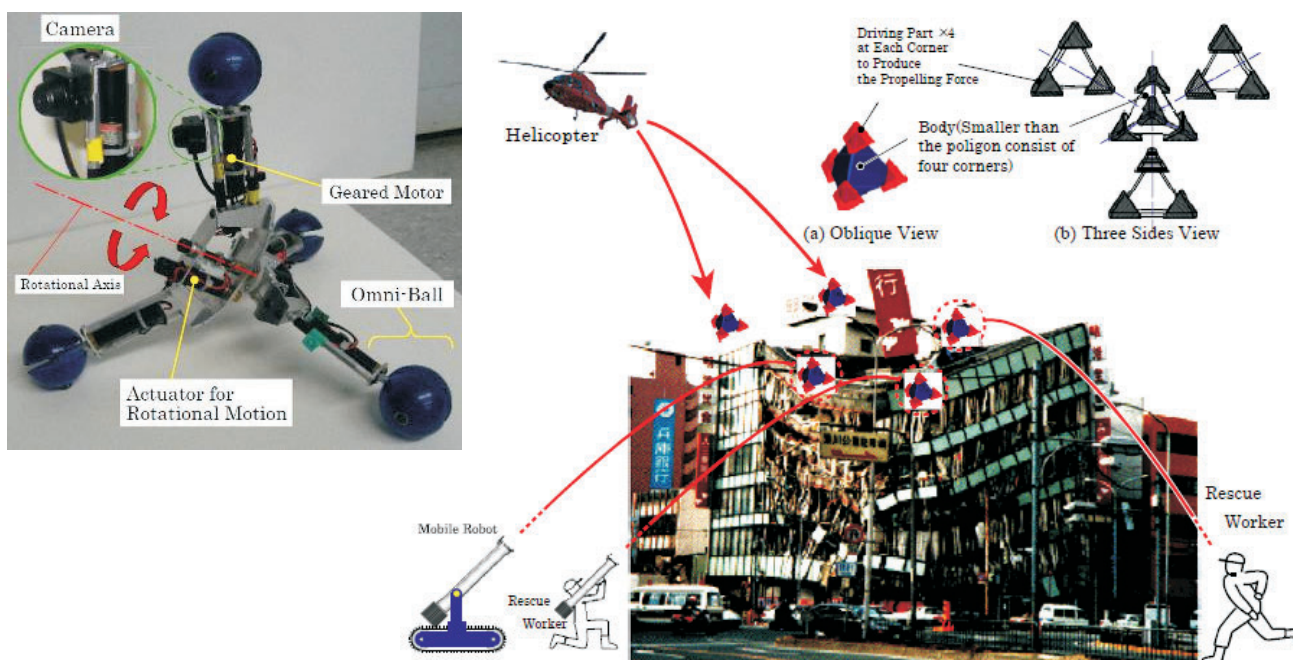


Fig. 1. Throwable Tetrahedral Mobile Robot and its use conception [3].

There are several throwable robots sold on the market, among others SpyBowl 360, Eye Ball, Recon Scout and EyeDrive. Almost each of those devices has a different construction idea of making teleobservation and tracing possible. [1], [5]

SpyBowl (Fig. 2a) is a device thrown or rolled towards the target. The device is made as aluminium body covered with rubber coating in form of a ball with 115 mm in diameter. Such a construction allows for the transport of large, repeated loads. It is equipped with four cameras allowing for the acquisition of static images (Fig. 2b) and with microphones transmitting the sound. The device can rotate about its vertical axis with speed of 0.22 rad/s, which allows us to watch all environment in dynamic way. Additionally the image can be seen from each camera independently. The range of the radio transmission varies between 20-30 meters inside building and 100-300 m outside. Entire device weighs 1 kg and can be thrown at the distance of 30 meters or thrown up to the height of 6 meters. Operating time on a battery is 45 min. The main application place of the SpyBowl device are closed rooms and buildings in the action zone of military and police special forces. [1], [5]



Fig. 2. Throwable robot SpyBowl (a) and the view of one the robot's cameras (b) [5].

A similar device, regarding design, is Eye Ball R1 (Fig. 3). It is designed for throwing at the distance of 50 meters, rolling or dropping. It provides an audio and video transmissions in real time. The device is used in tactic operations, where special forces take the advantage of newest information about situation in given

place, straight before entering upon an intervention. The device has one camera providing a good quality picture to 23 meters. In order to collect complete information about the environment the device rotates about its own axis with the speed of 4 turns/min. Thanks to an extra software it is possible to acquire a panoramic view. Besides, the device has near infrared illuminators of the range of 8 meters and thanks to them the camera is able to see in the darkness. The microphone has the range of 5 meters. Operating time on battery is 2 hours, in stand-by mode - 24 hours. Radio and video transmission takes place at a distance up to 125 meters depending on the environment. [1], [4], [7]



Fig. 3. Throwable robot Eye Ball [7].



Fig. 4. Robot EyeDrive [7].

The third interesting device for teleobservation and tracing is the Recon Scout robot. It is a mobile two-wheeled robot with titanic body and wheels from the urethane plastic. Such a construction allows throwing the robot at the distance up to 31.5 meters and dropping from the height of 9.1 meter. Moving forward is enabled by the so-called tail, which is the robot's support. Robot's parameters are following: width 187 mm, wheels diameter 76 mm, speed 1,1 km/h, range inside the building to 30 meters, outside 76 meters, working time 1 hour. The robot is equipped with black&white camera with sensitivity of 0,0003 lux. Due to small size it succeeded to obtain a total weight of the device - 0.544 kg. [1],[6]

The last presented robot is EyeDrive (Fig. 4). This is a four-wheeled robot produced in Israel (with the possibility to use a caterpillar track) operated by a single man. The robot can be thrown up to 3 meters high. The system of cameras allows for obtaining a panoramic view with image definition of 2500x570 pixels. The microphone transmits sound from the distance of 10 m. The robot's

range inside the building is 70 meters and outside to 300 meters. Operating time on battery is 3 hours and in stand-by mode - 24 hours. The robot's weight is 2.3 kg, there is a possibility to carry additional loads (sensors, explosives, etc.) weighing up to 3 kg. [1], [7]

Summing up the review of throwable mobile robots we can presume that the future of robotics and consequently of mobile robots looks promising. According to the development of technology and electronics we can expect a wider use of remotely controlled and autonomous devices. They assure safe accomplishment of the task without endangering people's life. The only eventual loss can be damaged technical unit. [1]

3. Throwable tactical robot

3.1. Device conception

Throwable tactical robot (TTR) has been designed for active teleobservation in military, police and rescue applications. It is a solution for threats which brings reconnaissance done by special forces before starting the action.

TTR is a device, which can be placed at the target area from a considerable distance and then survey it while being teleoperated. The camera and microphone placed inside the robot and its mobile abilities result in it being a perfect reconnaissance device limiting significantly the risk of health or life loss of a group members performing actions in the dangerous area. In assumption the TTR can be equipped with additional external device, the so-called rucksack, which enables to carry specialised charges: flashbangs, deafening and explosives. Additional equipment enables TTR use for explosive charges neutralization by pyrotechnic troops or making disorganisation and panic in the aggressors group.

The construction of the robot has been developed as a part of the development project for which Table 1 contains the assumption data. The design work over the robot has been partially supported by analysis done with the usage of MD Adams and Ansys software.

Two different models of the device have been evolved. According to the first solution (Fig. 5), the robot was supposed to have a trunk, being at the same time the running gear.

The first idea has been abandoned, because of the foreseen technological and technical difficulties with mounting and exploitation.

The second conception of the robot's construction developed in the project is described in point 3.2. It is characterized by greater compactness and functionality thanks to the ability to join additional load to the trunk. It was not possible in the previous version of the device.

Table 1. The desired parameters of the throwable tactical robot.

Parameter	Desired value
Robot's weight in standard version	1 - 1.5 kg
Weight of additional load	0.1 kg
Weight of control panel	6-8 kg
Maximum speed	3 km/h
Throwing range	20 m

Discarding height (limiting)	9 m
Range inside building	30 m
Range in open space	100 m
Standard equipment	Camera, microphone

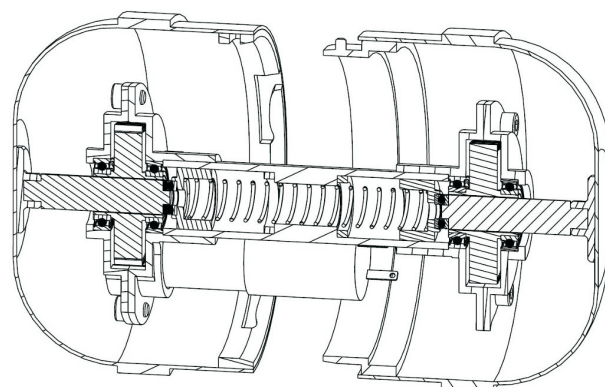


Fig. 5. The first conception of TRM's construction (section).

3.2. Robot construction

Robot's body (Fig. 6a) is a specially formed cylinder which is an assembling base for all construction elements both outside and inside. Inside the body there are made ribs for double purpose. They are the elements which strengthen the shell of the body against deformation and fix the components of the robot. Thanks to the internal ribs it is possible to easily mount electronic boards on one side (Fig. 6b) and the battery on the other (Fig. 6c). In the central part of the body the camera and microphone are fixed. A special micro junction is used for connecting the robot to the additional operational load, the so-called rucksack, its detection and releasing.

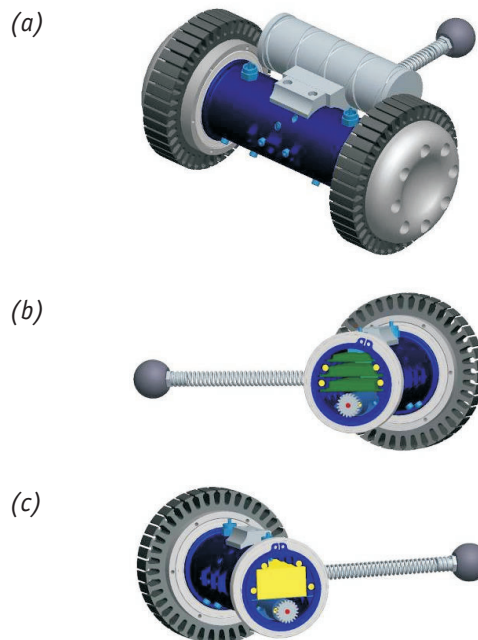


Fig. 6. Construction design of TTR: additional device „rucksack“ (a), position of electronic plates (b) and battery (c).

The engines are seated in properly formed sleeves attached to the body. Wheel rims are fixed to external extreme parts of the body by means of the bearings. Here,

the kind of the bearing is very important because of its wear as a result of an impact, friction and price. Drive transmission is a result of meshing of the rack embedded in engine axis and inside gear embedded in the rim. As an overload coupling for the protection of gears and the engine there are applied micro rubber blocks placed in cut-outs of the ring with internal teeth. They enable gradual angular shift against the rim.

The made prototypes of the device and control panel are shown in Fig. 7 and the most important parameters of the device are presented in Table 2.

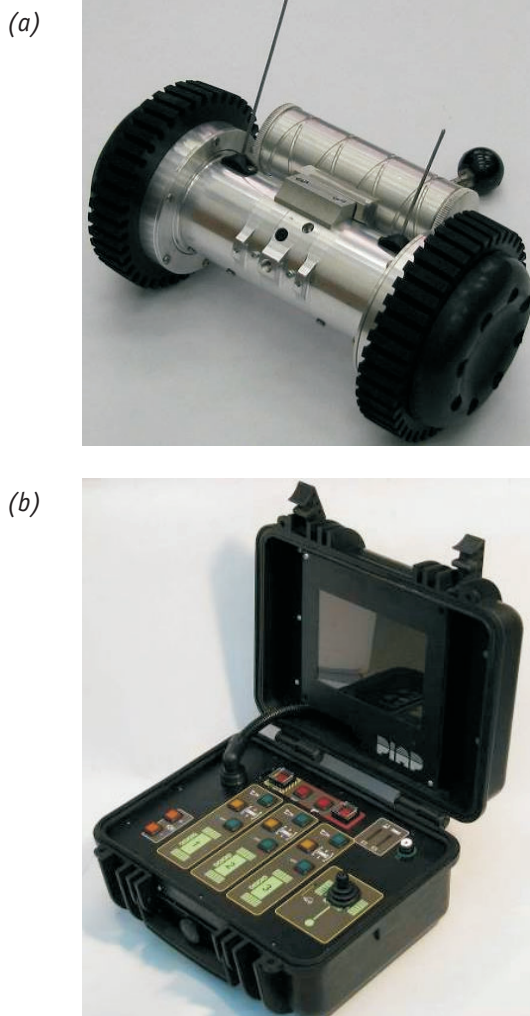


Fig. 7. Prototype TTR (a) and control panel (b).

Table 2. The most important parameters of the throwable tactical robot.

Parameter	Value
Robot's weight in standard version	1.3 kg
Weight of additional load	0.16 kg
Weight of control panel	7 kg
Robot size (width/ height/length)	205/100/210 mm (with tail)
Control panel size	360x340x194 mm
Maximum speed	3.3 km/h
Maximum ramp angle	25 deg
Throwing range	15 - 20 m
Discarding height (limiting)	7 m (9 m)
Range inside building	30 - 110 m

Range in open space	120 - 150 m
Standard equipment	camera, microphone
Radio transmission	telemetry, vision
Operating time	≈ 1 h
Control panel operating time	≈ 4 h
Maximal number of controlled devices	3

The range of robot mentioned in Table 2 directly depends on environmental condition of the radio waves propagation.

Shock absorption on contact with the ground after throwing is assured by appropriately cut T-shape tread on the wheel. The additional sideways shock absorption is assured by rubber straps.

High maximal robot's speed is 3.3 km/h and enables to perform inside reconnaissance efficiently and time sparing. Higher speed value would be a significant obstruction for the operator so the reached result seems to be optimal.

The device is switched on in non-standard way, that is, by turning the wheel and switched off remotely from the console or after longer inactivity time. Such a switching on should make it service easier by the operator wearing gloves. In order to save energy the device automatically limits power consumption by unused components. The robot is provided with an internal connection which helps to communicate with other robots and initiate explosives.

The electronic part of the device is divided into following functional blocks: supply module, micro controller with peripheries managing the model's functions, engine drive programmer, vision transmitter, telemetry receiver, interface scheduling CAN BUS.

Cameras with good optical characteristic, working also in infrared band are applied in the device. The advantage of such a solution is operating the robot in insufficient lightning and in the darkness what results with better picture quality and makes the work more comfortable.

3.3. Control panel

Control unit has form of an unfolded box of 330x234x170 mm and weight 7 kg. A special construction assures high stiffness, shock and bending resistance. The box has a special seal which effectively protects it from sand and dust and assures complete water resistance and water-proofness up to 10 meters. Material, which the box is made from, is very durable in temperatures from -33°C to +90°C and resistant to oils, lubricants and other aggressive substances.

There are positioned antenna, monitor and two loudspeakers in the box lid. Application of directional antenna enables to acquire high power gain and directivity of radio beam. Additionally small size of the antenna enabled to build it in completely in the box lid what protects it from mechanical damage and increases functionality of the control panel. The operator observes the picture from the device camera on the monitor and through loud speakers, that are built in on monitor sides, can hear sound from the microphone installed on the device. The use of the monitor with a TFT matrix allows for obtaining a picture of better quality and brightness than the usual LCD matrix. The

TFT matrix assures lower power consumption as well, which is essential in case of battery use. The control desk is positioned at the bottom of the box. It is equipped with one joystick and push-buttons responsible for operating different device functions. Behind the control desk (synoptics) are placed all the electronics controlling the control panel and the exchangeable battery package.

The control panel is divided into modules of synoptics, mainboard and transmission. It should largely facilitate servicing and operating the control panel. The control panel is supplied by exchangeable eight-cell lithium-polymer battery package. It is characterized by low self-discharging so it can be stored for a longer time without recharging. Additionally there is no memory-effect in its case. The exchangeable battery pack is integrated with the side grip of the operating panel what enables fast battery change. In the front part of the control panel are audio-video junctions enabling recording and reproduction of registered actions.

Three devices can be controlled from one control panel independently. It increases the functionality of the set and reduces the risk of the device uselessness in case of radio contact loss between the device and control panel or device damage. Possibility of switching among three devices allows also for having three independent observation points.

Special electronic systems built on base of single-system processors are designed for the control panel needs. Those systems are optimized due to EMC interferences, thermal overload or errors of transmission and adequate standard signal.

The control panel is designed as a general-purpose one. On the PCB panel of the control panel are placed 2 joysticks and 28 push-buttons, where 16 are illuminated. Additionally there are 3 diode lines. All elements can be used in an arbitrary way according to the needs.

3.4. Tests of the robot and the control panel

For the robot prototype was done number of tests in various conditions.

The first test consisted in performing a series of 20 throws of the device at a distance of 15-20 meters in a straight line on concrete base. Pending those throws there was no construction damage, it means, the device was still fully operative and ready to follow commands from the control panel.

The second test consisted in throwing the device into rooms through the open window (Fig. 8a). It enabled to work out the throwing technique, its evaluation and precision. In that test there were no damages, neither mechanical nor control system.

The third test consisted in series of dropping from the height of the 2nd floor, that is, from about 9 meters (Fig. 8b). The fall from such a height enables to acquire speed of 48 km/h. It follows from the tests that this case is the most difficult and demanding. In the worst case the full load is received and transferred by one wheel and bearing to the body construction. In result of the tests there were changed the rubber strap on the rim dispersing and absorbing the fall as well as the ball bearings to crosswise roller bearings.

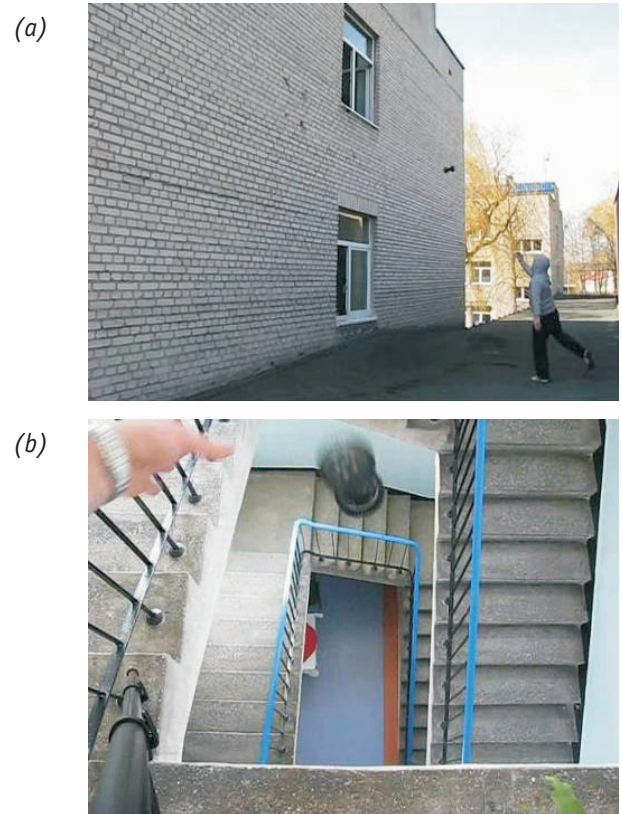


Fig. 8. Throwing tests into a room (a) and dropping from the second floor (b).

The aim of next tests was to determine limiting range values of telemetry and vision transmitter. One of the most essential questions was to study possibilities to move inside buildings. It is well-known that constructions of most buildings are made of reinforced concrete. Such a building construction causes both strong suppression and dispersion of electromagnetic waves. The most frequent result is the loss of radio communication which makes further control of the device impossible. In most cases the vision data are lost firstly, which prevents the operator from visual control over drive direction. The next is loss of telemetry range. After losing the image there is possible to transmit the sound. In some cases only listening is sufficient, however it limits evidently possibilities to acquire valuable information about dangerous situation.

The telemetry and vision range was satisfactory up to 100-110 meters. Both transmissions had continuous and non-disrupted character enabling efficient task performance. The result is impressive regarding small size of the device, considerable proximity of ground introducing noise and just coincidental shading of a direct view between the panel and the device. Tests in open area demonstrated that the transmission range is not shorter than 110-150 meters. It offers great opportunities for the device application not only to inspect car's chassis but all kind of reconnaissance around buildings or other device of special purpose. The reconnaissance zone is large enough to recommend usage of this device by military pyrotechnic troops, police and rescue units. Application of additional load allows for taking a counter-load and its detonation in justified cases.

During further tests there was done a drive down the stairs to the basement in the building with limited illumination and space reconnaissance with use of the camera working in infrared mode. All stairsteps were surmounted autonomously without operator's intervention. Both orientation in the corridor and reconnaissance were performed at moderate light which allowed for testing the quality of the picture sent by the device and determining the device usability in such conditions.

At moderate light it was possible to observe the basement and identify detailed furnishings. The robot's camera was not equipped with illuminators so for observation of places like a basement an infrared radiation must be provided. Nowadays works on attaching an illuminator are conducted what can enable to do a reconnaissance in total darkness. There will be tested diode illuminators of visible radiation and infrared radiation.

The next tests consisted in driving down the stairs (Fig. 9a). They were the simplest due to easy access to the staircase, its large space and good illumination. During the decent the picture observation is not possible due to fast frame changing and variation of direction of camera view. The descent itself has rather random character. It does not cause any danger neither for the device nor the environment. The worst case that can happen is rotation around the longitudinal axis and driving the stairs sideways. In this case the device gets pretty large rotation speed and large driving down speed and the operator is not able to control the drive till the moment when the device stops.

In the next tests the throw range of the device was examined (Fig. 9b). Because the construction weight is 1 kg the throw range depends on a large measure on the thrower. The obtained results of 15-20 meters depends additionally on the way of falling, that is, if the device starts to overturn at touchdown.

From obtained results we can conclude that the thrower should have no problems by delivering the device both to a long distance and i.e. roof of a one-floor building.

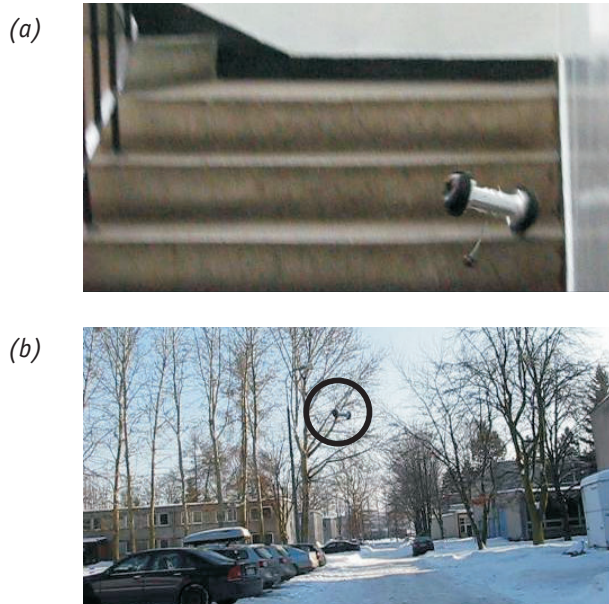


Fig. 9. Tests of driving downstairs (a) and distance throwing (b).

There were performed tests in the arrival hall at Okęcie Airport as well (Fig. 10a) in co-operation with the Border Guard. The hall is characteristic due to its construction, which is reinforced strongly and has a lot of steel construction elements. Such conditions cause a special problem for radio modems due to strong damping of radio signal and a large number of signal rebounds from those constructions. Test drives were performed in time of normal flight service in order to show real operational use closer and to obtain additional factors that can influence the communication quality with the device.

Performed tests allowed to cover the distance of 80 meters on the way between screening plan of terminals T1 and T2. Additionally tests drives were done between separate transporters due to maximize quantity and level of interferences both from the transporter construction and its work. The reconnaissance proceeded without significant problems although the device was screened directly through protective elements of the luggage transporter.

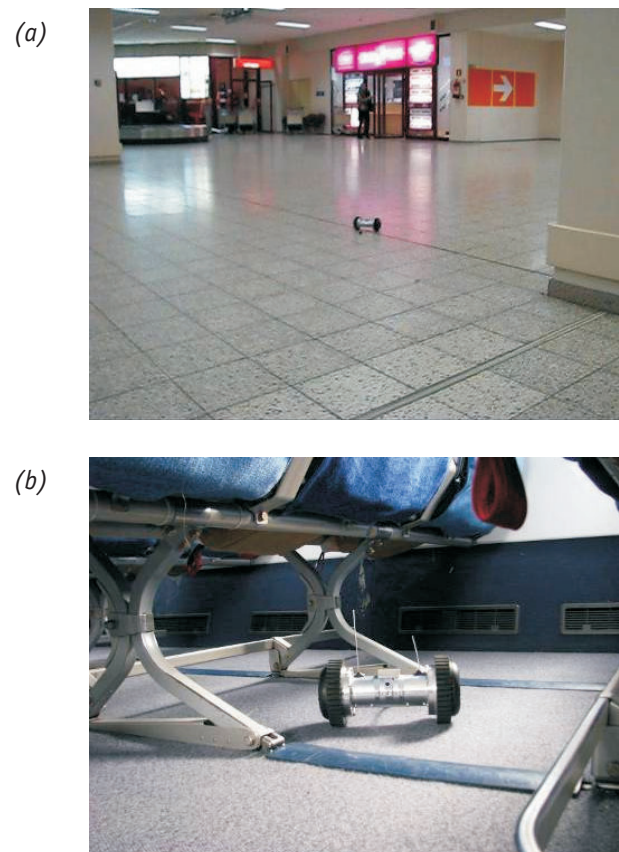


Fig. 10. Device tests in the arrival hall of Okęcie Airport (a) and on the board of Boeing 737 (b).

Special tests were performed on the board of Boeing 737 of Polish Airlines LOT (Fig. 10b). Their task was to present possibilities to do reconnaissance in a very difficult place like passenger cabin. The problem results from small device size and large number of elements generating disturbances. Support elements of the seats are a very dense obstacle for propagation of waves and generate a large number of reflections diminishing primary radio signal. In such special circumstances the radio communication and possibility to access each corner of the fuselage of the aeroplane construction was tested. The tests

of the device were performed in this Boeing model due to its significant popularity and in connection with great probability of necessity to reconnaissance just this construction.

During tests the reliability of load release mechanism was tested (Fig. 11), both on the mechanism and the software. The use of explosive charges should, depending on the character of the special forces actions, introduce chaos and panic amongst aggressors and lead to neutralization of dangerous and dubious packages on spot.

It enables the large spectrum of using the device in potential events and scenarios.

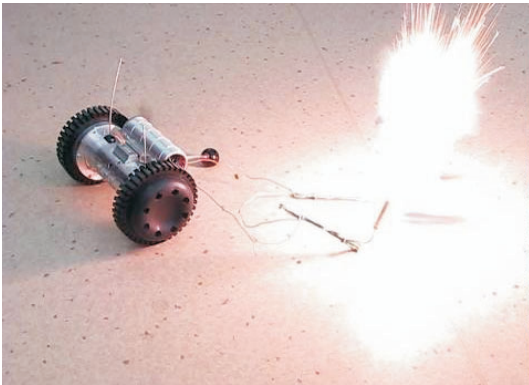


Fig. 11. Reliability tests of the mechanism releasing explosive charge.

Additional load can carry different materials, including explosives, deafening and blinding charges. The character of applied material depends in every case on the kind of activity and usage context. You should take into consideration that in case of using explosive material the device will be destroyed without chance to repair it. The cost that it will entail is not of great importance due to the fact of using it in special, rescue or other actions.

Films presenting selected versions of the robot are at the link [8].

4. Summary

In this paper the construction and working mode of the throwable tactical robot and its control panel is presented.

Test results testify that the robot is resistant to the downfall caused by throwing down, descent or dropping from the second floor. The shape and mass of the robot enables to throw it at the distance of 15-20 meters or to the roof of one-floor building. Application of the camera working in the infrared mode enables a reconnaissance by meanlight. The robot copes very well in surveying not easily accessible spaces and places where the radio communication is difficult. The communication range enables teleoperating the device both in open area and in rooms adequately to 110 and 150 meters. The transmission ranges obtained in these cases are highly satisfying considering the size of the device.

Such attributes of the robot predispose it to active teleobservation in military, police and rescue use. Additional equipment allows to use TTR to neutralization of explosive charges by special forces. The robot enables to limit the risk of health or life loss or group members performing actions in dangerous areas.

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