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CONCEPT AND DEVELOPMENT OF ENGINEER MISSION SUPPORT ROBOT

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Abstract

Contemporary battlefield is more and more demanding environment after all for soldiers but also for their equipment and machines that assist them. Looking at the last Lessons Learned experience we can conclude that the most dangerous threats met during last asymmetric warfare were Improvised Explosive Devices (IEDs). Therefore, the main focus is being done to equip UGVs with efficient engineering equipment that allows operating very quickly in very dangerous environment being exposed to health risks and loss of human life, within more and more sophisticated engineering support missions with special regard just to EOD/IED missions. The concept of such an engineering robot design is described in this paper.

The EOD/IED mission support engineer robot, the attachments of the EOD/IED mission support engineer robot, removal of car bombs by means of the robot's attachments, the EOD/IED mission support engineer robot's ability to overcome terrain obstacles, the mission support engineer robot's remote control panel are presented in the paper.

Technological and Operational Problems Connected with UGV Application for Future Military Operations was held in Rzeszow, Poland on 20-22nd April 2015.

Keywords: *Unmanned Ground Vehicles, robot, Human Machine Interface*

1. Introduction

Some issues presented in this paper were also discussed and some materials were presented during the 35th Applied Vehicle Technology (AVT) NATO Science and Technology Organization Panel Meeting Week within Specialists' Meeting AVT-241/RSM-022 on: Technological and Operational Problems Connected with UGV Application for Future Military Operations that was held from 20-22nd April 2015 in Rzeszow, Poland.

Asymmetric character of contemporary warfare causes imbalance in the means of power, resources and costs resulted from this asymmetry. In consequence, armed forces need to develop complex and expensive operational capabilities and their application methods in order to fight against relatively simple and inexpensive techniques used by irregular enemy troops or terrorists [1].

Modern battlefield and the operations of rescue services in peacetime missions generate risks to the human live. Improved effectiveness of such an operations can be achieved through the usage of remote-controlled unmanned ground vehicles (UGVs) equipped with manipulators and tele-operator system. Then, the operator is removed from the zone of immediate danger to life and health, and the robot's operational capabilities allow him to perform dangerous tasks in extreme conditions.

The scenarios in which can be foreseen the use of unmanned ground vehicles both in peacetime and on the battlefield, impose very high demands on both their drive systems and control systems. The basic requirement for this kind of solution is the provision of a high degree of mobility and precision of control in the conducting of reconnaissance and rescue missions, the approach and neutralization of dangerous charges, as well as sufficient forces and torques of the working equipment The progressive development of hydraulic elements, their reliability and capability to be remotely controlled means that hydrostatic drive systems are increasingly used in the drive system solutions of modern unmanned ground vehicles. Such hydrostatic drive systems provide both high performance vehicle traction and sufficient power for their attachments [2, 6].

An undoubted advantage of this kind of technology is the relatively long operational life of unmanned ground vehicles (UGVs), limited only by the capacity of the fuel tank (powering their engines), compared to robots powered by electric drive systems, whose working time is limited by the capacity of their battery cells. Full use of the potential of these drive systems requires the introduction of modern control systems. The advent of new technology for the control of hydraulic sub-assemblies – the CAN-bus system in its mobile version – has opened up new, long-awaited possibilities in the field of control of attachments and the operating processes of machines and vehicles equipped with hydrostatic drive systems [3-5].

2. The requirements for engineer EOD/IED mission support robot

One of the toughest and most dangerous combat tasks for engineer mission support robot is the identification, removal and neutralization of mines, munitions and unexploded ordnance, known as UXO, and improvised explosive device known as IEDs. Undertakings of this type are handled by special EOD (Explosive Ordnance Disposal) engineering detachments. An increase in the safety of soldiers involved in such missions requires the use of support robots capable of:

- handling all kinds of artillery, rocket and bomb type ammunition weighing up to 200 and even 500 kg with a diameter of 80 to 600 mm,
- handling all kinds of barrels and bottles weighing up to approx. 250 kg and containing potentially dangerous and hazardous substances,
- removal of suspicious vehicles and other objects by pulling, flipping, pushing, etc.,
- neutralization of dangerous explosive charges placed in trucks.

Efficient removal and neutralization of UXO – especially in urban areas, where due to the threat to the population, buildings and infrastructure such ordnance cannot be detonated where it is found – requires:

- ability to handle the following ordnance lying on the surface or partially buried in the ground,
- mortars with a diameter of 60-120 mm (weighing 0.5-3 kg) – spherical in shape,
- artillery ammunition with a diameter of 60-155 mm (weighing up to 50 kg) –cylindrical in shape,
- air delivered bombs weighing up to 250 kg and with a diameter of up to 500 mm,
- anti-tank mines with a diameter of 150-350 mm (weighing up to 10 kg) – low cylinder in shape,
- anti-infantry mines – various shapes with dimensions of 20-100 mm,
- gas filled cylinders – with a diameter up to 400 mm weighing 80 kg – cylindrical in shape,
- barrels filled with fuel or chemicals – with a diameter up to 600 mm, weighing up to 250 kg,
- ability to handle concrete blocks and elements, such as those disguising IEDs, weighing up to 200 kg (manually placed by 4-6 people), flagstones, curb stones, (hexagonal concrete) paving stones, concrete rings and drainage pipes, etc.,
- lifting of construction elements that restrict access to the UXO or IED, such as:
  - wooden poles and trunks,
  - concrete traction poles up to 8 m in length,
  - floor slabs (weighing up to 1000 kg),
  - steel trusses,
  - steel sections (rods, angle bars, pipes, etc.),

– ability to unload hazardous materials from transport vehicles and loading units disguising or containing hazardous materials – e.g. euro pallets, trays or containers,
– pull, push or lift car bombs – weighing a minimum 1500 kg (passenger cars) – preferably up to 3000 kg (pick-up trucks and vans) [7].

3. Design of the EOD/IED mission support engineer robot

Based on the defined tasks imposed on remote-controlled, unmanned ground vehicles in EOD/IED missions, a design solution was proposed based on a 6 x 6 wheeled drive system, which provides the ability to develop high driving forces and overcome obstacles (Fig. 1). Its effective operation in field conditions is dependent on a suitable suspension system – hence a swing arm type suspension was used in the developed robot, providing each wheel a stroke of 0.5 m to ensure its wheels constant contact with the ground when negotiating terrain obstacles. The swing arms are pivotally mounted to the chassis on which attachments are mounted. The anchorage is deliberately weakened structurally, so that in the event of a detonation under a wheel – the swing arm becomes detached, and does not shift loads to the chassis of the robot. Furthermore, in order to facilitate any repairs and servicing, the engine on its mountings and the system of pumps and fuel tanks are designed and located on an additional frame, allowing them to be easily slid out.

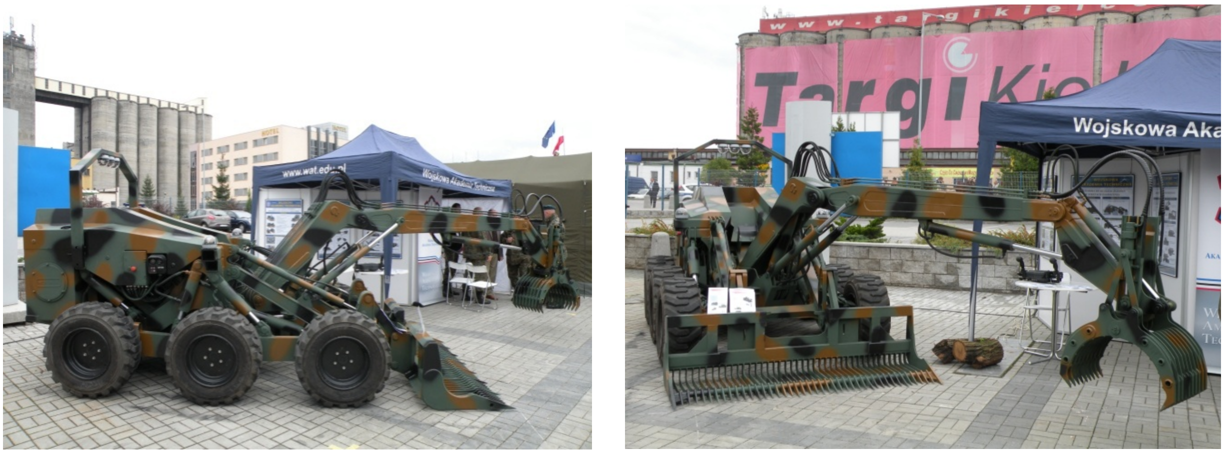

Fig. 1. EOD/IED mission support engineer robot

For high manoeuvrability and to ensure the possibility of adjusting the robot's position in its workplace, in a confined space – a flatbed steering system is used. However, this causes the formation of high lateral forces acting on wheels during a turn. For these reasons, special tires and wheel rims are used in a skidder type drive system. The tire size is selected in such a way so that the pressure on the ground as determined by MMP (Mean Maximum Pressure) does not exceed 170 kPa and ensures a good level of mobility in terrain with a low load capacity.

In order to ensure its effective performance of tasks, the robot is equipped with two cooperating attachments (Fig. 2):
– a loader attachment – used for clearing a path (removal of obstacles, pushing vehicles, etc.), lifting/overturning bulky objects (e.g. cars), digging out shallow buried UXO, anchoring in order to increase the power developed by the manipulator and as a support increasing the stability and load capacity of the manipulator,
– a manipulator attachment – used for handling, moving and loading dangerous objects – featuring the ability to cover a large workspace, enabling it to reach into roadside ditches and craters, and to load and unload cars.

The bucket has been designed to be suspended from a boom using a standard quick coupling for mini-loaders, allowing, if necessary, to be rapidly replaced by any other tool available on the commercial market (grabbers, buckets, hammers, drills, etc.) or specially designed equipment, e.g. detectors, radars, trawlers, neutralizers, or even catapult type weapons. Based on analysis, the kinematics of the manipulator makes it possible to achieve a high degree of compactness on the march and in the transport position – its height does not exceed 1.8 m and its width 2.0 m. This allows the robot to be transported inside an Mi-8 helicopter (with which the Polish Armed Forces are equipped) in the hold of a CASA-295 aircraft (with which the Polish Armed Forces are equipped), inside a standard 20' container, on the load floor of a medium-duty vehicle (e.g. a Star 266 truck) and on lightweight low loader trailers and roadside assistance vehicles. This ensures a high degree of transport mobility and the ability to begin operating immediately.

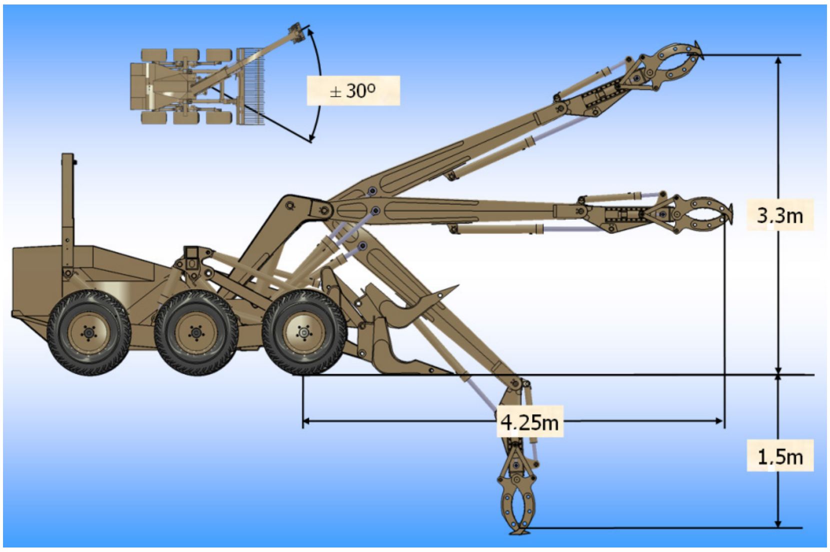

Fig. 2. The attachments of the EOD/IED mission support engineer robot

The advantage of manipulator's adopted system of kinematics is the speed and ease of transition from marching position to a position in which to handle objects – thanks to its parallel motion construction, breaking open the attachment involves only one servomotor and does not require corrective movements or the setting of other manipulator parts. The working area of the manipulator does not interfere with that of the loader attachment, allowing for their effective cooperation and the development of considerable technological forces. The manipulator is equipped with a special operating and grabbing head adapted to handle objects of varying size and weight, but also to pull, push, lift and overturn bulky objects (Fig. 3).

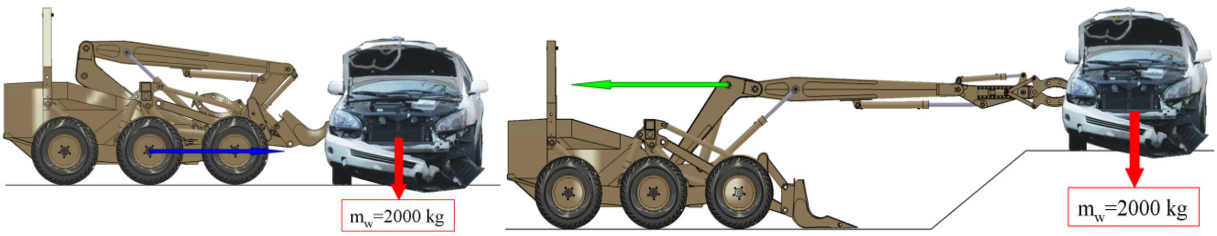

Fig. 3. Removal of car bombs by means of the robot's attachments

The need for rapid action in EOD/IED missions means that very important features of the mission support engineer robot are its vehicular speed, ability to overcome obstacles, and the ability to remove terrain obstacles – factors determining the time taken to reach the explosive charge to be handled. Currently produced robots, built on a mini-machine basis do not travel at a speed above 10 km/h and are not able to travel over a parapet with a height greater than 0.2 m. Improvement of these parameters requires the use of special chassis system solutions. The robot's designed kinematical suspension solution, combined with its hydrostatic drive system provides it the ability to attain speeds of several dozen kilometres per hour, the ability to climb parapets/walls with a height of 0.5 m, and substantially uneven terrain (roadside ditches, drainage ditches, shooting trenches, embankments, and rubble – Fig. 4).

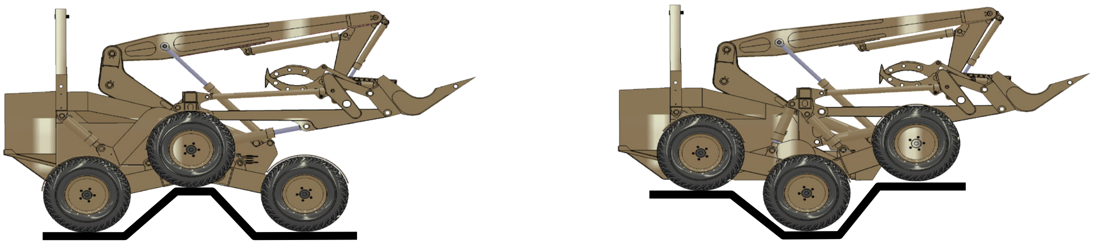

Fig. 4. The EOD/IED mission support engineer robot's ability to overcome terrain obstacles

4. The EOD/IED mission support engineer robot's human machine interface (HMI)

The control system for an unmanned ground vehicle should ensure:

- high degree of operational reliability,
- high degree of resistance to interference,
- ability to control approx. 20-30 unmanned vehicle functions,
- ability to control multiple operational movements at the same time,
- ability to proportionally control selected operational movements,
- ability to cooperate with on-board computer systems,
- ability to send feedback information to the control position.

For this reason, the mission support engineer robot's control system is based on two CAN sub-networks, communicating with each other in order to exchange control information and data concerning the vehicle status, one of which is located on the vehicle, and the second being a remote control panel with an integrated CAN controller (Fig. 5). The proposed solution in the CAN standard makes it possible to control both the drive system and the attachments as well as a system of rotating video camera heads. The logic sub-network base module on the vehicle is a *programmable logic controller* (PLC), whose task is to read the control information from the control panel, correctly interpret it and execute the orders. At the same time, it serves as a programmable safety component, which diagnoses the condition of the vehicle and prevents the performance of orders that could potentially jeopardize the robot.

Fig. 5. The mission support engineer robot's remote control panel

5. Summary

The mini construction machinery like skidders, mini diggers are not adaptable in a simple way to fulfil military missions like detection, identification, handling and destroying of Improvised

Explosive Devices (IEDs) which are the urgent tasks of engineers at the current, asymmetric battlefield. The low vehicular speed of these machines and their inability to assess their own stability in the tele-operation process significantly prolongs the time taken to perform tasks and limits their operational capabilities. Thus, the specific nature of the tasks carried out in EOD/IED missions requires the construction of machines with specific operational capabilities, equipped with attachments and dedicated remote control systems in a tele-operator arrangement. The presented concept for an EOD/IED mission support engineer robot shows that it is this type of solution. The tests and studies carried out have confirmed the correctness of the adopted structural assumptions, choice of power train, chassis and drive remote control system. The results of these studies were presented during the 35th Applied Vehicle Technology (AVT) NATO Science and Technology Organization Panel Meeting Week within Specialists' Meeting AVT-241/RSM-022 on: Technological and Operational Problems Connected with UGV Application for Future Military Operations that was held in Rzeszow, Poland on 20-22nd April 2015. There was also presented EOD/IED mission support engineer robot among other seven UGVs. There is a movie from dynamic demonstration on the website: http://www.cso.nato.int/page.asp?ID=3202. The presented operational parameters of the robot's operational attachments in selected EOD/IED mission tasks show that it meets the requirements for this type of machine, used to perform tasks in the context of military missions at the contemporary battlefields.

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