MEANS TO ENSURE SECURITY OF PORT INFRASTRUCTURES UNDER WATER

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Abstract: *Numerous are the tools that configure security and protection systems for port infrastructures. At the same time, very few are the tools that have been developed in the Republic of Bulgaria and are being implemented in a number of countries around the world. This report presents tools / systems that provide security for the outer perimeter / outer boundary of the port security system and those that provide "internal" security to the internal perimeter of port infrastructures. These are the hydro-acoustic system developed by Hi-Tech IMS Ltd. for providing the so-called "Outer" security and underwater robot "ARMUS", providing the so-called "Internal" security of the underwater security systems of port infrastructures. Both systems are exceptional developments in the company and could successfully secure underwater security at the seaside. Both systems are new to Bulgaria, and the underwater robot has no analogue in the world with its features.*

Keywords: *HYDROACOUSTIC SYSTEM, UNDERWATER ROBOT, HARBOR PROTECTION, SURVEY OF LARGE VESSELS*

1. Introduction

The configuration of the systems providing security and protection for port infrastructures depends on a number of factors and, above all, on the objectives and tasks that are being set in place in their construction and operation.

According to military tactics and strategy, the adjacent seaport security zones are [1]: Outer Zone, "O" - the area is provided by means of long range acoustic sensors; Middle Zone – "M" - the area can be surveyed by active sonars and the Inner Zone – "I" – originates from divers and small autonomous or remotely controlled Underwater Vehicles – Fig. 1.

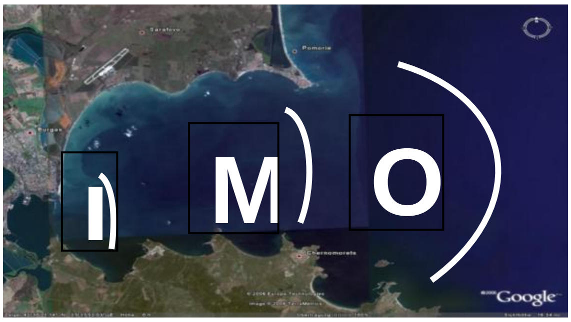

Fig. 1

If we accept this separation of the security zones, we can state that in this report, by the Hi-Tech IMS Ltd., will be presented products and systems that can successfully perform tasks of providing and guaranteeing security in the "M" and "I" zones. These devices and systems are, a hydroacoustic under and above water communication system and an underwater robot for study of the hulls of large vessels. The first system is capable of successfully operating in the "O" zone and solving all the tasks assigned to such systems, and the second - the ARMUS robot is able to be a valuable port facility assistant while providing security in the "I" security area.

Of course, these two systems are just a small part of the integrated security and protection systems for port infrastructures, but they are one of the few that are Bulgarian development and which operate in real environment.

The purpose of the report is to present the advantages of both systems and the possibilities for their self-application and/or use in a system.

The report will not address issues of protection provided by such systems, such as the use of non-lethal means. The latter may be different for purpose underwater acoustic and pneumatic devices, charges with non-lethal effect and many others [2,3]. Hi-Tech IMS Ltd. has developed and owns such tools, but this aspect of the integrated systems - the defense will be presented in subsequent publications.

2. Hydroacoustic Security Systems

2.1 State of the art in the field of hydroacoustic buoy systems

There is information about a number of hydroacoustic systems, based on a hydroacoustic buoy with different characteristics and parameters. One of the basic is the depth at which the buoy is positioned. It ranges from several tens of meters to several thousand meters under the water. For example, for new experiments in ultra deepwater the Leibniz Institute at University of Kiel in Germany [4] uses Resinex syntactic foam blocks to be used at a depth of 4,000 meters and at 6,000 meters – Fig. 2.

On another hand, the Italian company Resinex [5] has developed and uses hydroacoustic system in an integrated water monitoring system and anti-tsunami alert. It is 10 Pem 43 buoys, 4,3 metres of diameter and 2 metres in height. They are able to produce a net buoyancy of 23 tons and are positioned at a sounding depth of 150 metres in a stretch of water where the current reaches 1 m. a second with waves of up to eight metres – Fig. 3.

***Fig. 2** Resinex syntactic foam blocks*

***Fig.** 3 Pem 43 buoys*

And the last but not the least at the end of 2006 Resinex positioned hydroacoustic system in the South Tyrrhenian, a few kilometers off Palermo at a water depth of 2090 meters – Fig. 4.

Of course these and other developments of different organizations can be used for meteo CO2 monitoring and wave measuring, water temperature and salinity reading, etc. and to transmit this information by radio, hydroacoustic or satellite signals to shore and ship stations for processing, analysis and decision making.

Fig. 4

At the same time, they can also be used to identify underwater submarines, UAVs and ships on the surface. It is these latter capabilities, combined with the above, as well as reliability, disguise, maneuverability and user friendly software, make them great products and systems that can be successfully used to provide security for port infrastructures (but not just).

2.2 Hydroacoustic system „SCIAERHAB“

The system has been developed by a team[1] headed by Academician Stefan Vodenicharov.

As noted above, in the base of those systems is the hydroacoustic buoy. Hi-Tech IMS Ltd. EOOD has developed for the "SCIAERHAB" system the hydroacoustic buoy referred to on Fig. 5.

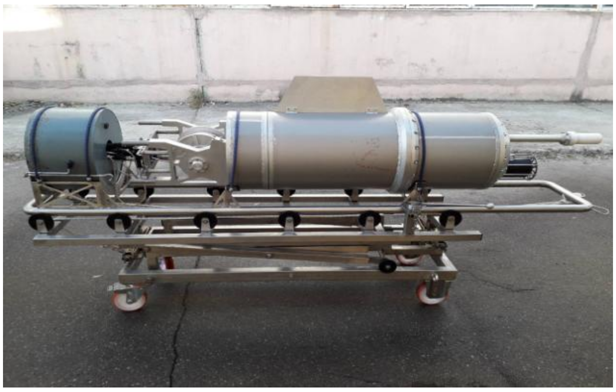

Fig. 5 *The hydroacoustic buoy, ready for demonstration*

But to get to this point when the buoy is ready for testing, we have come a long way. The whole process was carried out in full compliance with the requirements of modern organizational/standardization procedures for the development of products and systems and using the latest technologies in this field. For example, for the purpose of the product design we started with 3D design and modeling using FDM – Fused deposition modeling, as the most popular 3D printing technology – **Fig. 6**.

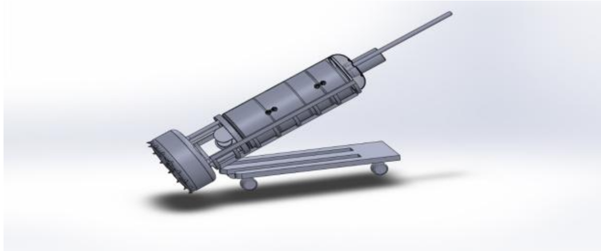

Fig. 6

„SCIAERHAB“ and in particular the hydroacoustic buoy were successfully tested on the 13th of October 2018, in the Tsarevo aquatory, and showed sustainable action of all the planned functions to be performed, including in extreme conditions - **Fig. 7**.

Fig. 7 *Tests of the buoy*

The characteristics and parameters of the buoy are a company secret, but what could be said about it, is its advantages, and that the same:

- has exceptional resistance to sea waves over 2 m.;
- shows high reliability when moving from depths of 100 to 200 m. to the sea surface, for dozens (hundreds) of cycles without interruption;
- in accordance with the requirements of the respective customers, it can be used for meteo CO2 monitoring and measurement, water temperature and salinity reading, for underwater identification of submarines, UAV as well as ships on the surface;
- uses standard protocols for radio, hydro and satellite communications for data transmission;
- ensures extremely low level of false alarms**;**
- it is easy for operation and maintenance;
- is highly adaptable and can be integrated into any marine observation and control systems.

Finally, it should be noted that the hydroacoustic buoy can become a reliable tool in an integrated port infrastructure security system, and not only to monitor and control certain segments of the maritime space, which it explores, but also to communicates and exchanges information with the other elements of the system. The latter is particularly important given the need to ensure of reliability, continuity, accuracy and completeness of the information, that must be sent to the control centers in a timely manner. This also applies to the possibility for communication between the buoy and the underwater robot "ARMUS", the information obtained by the buoy can many times reduce the time needed for the robot to examine the hulls of the large vessels.

3. Underwater hull observation systems

2.1 State of the art in marine vehicle inspection robots

The exploration of the hulls of large vessels, in terms of both their security (no matter if these hulls are not equipped with lime mines to be detonated in the port and cause massive losses with human casualties and material damage), and the security of the

[1] Nikolay Popov; Kiril Stoychev, Alexander Kolarov, Stoyan Kolev; Martin Lolov; Yasen Hadjitodorov; Stilian Georgiev; Ventsislav Pehlivanski, Vladimir Varbanov; Ivan Bogomilov; Radoslav Merdzhanov, Ilian Atanasov, Slavi Slavov, Nikolay Alexiev, Stoil Todorov

ports in which they land, is an important element of the integrated approach to the security of port infrastructures.

A number of underwater robots are known in the world practice, which apart from examining hulls to identify failures and hull roughness which plays an important role in the ship's speed and that directly affects the fuel consumption making the ship less environmental friendly, can also be used for security purposes in the ports, exploring the hulls for explosive devices placed on them.

Among them is "HullBUG" - Fig. 8 developed by SeaRobotics and funded by U.S. Navy Office of Naval Research (ONR) to tackle this issue.

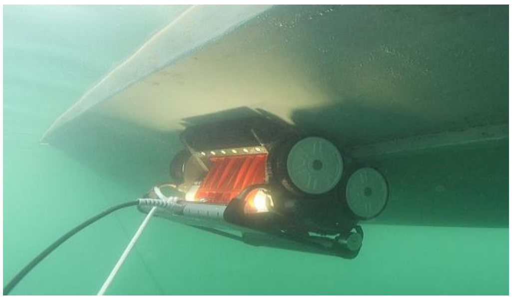

Fig. 8 *HullBUG hull cleaning robot*

The Robotic Hull Bio-inspired Underwater Grooming tool (Hull BUG), is a small autonomous vehicle weighing 30 to 40 kg. It uses four wheels and attaches itself to the underside of ships, using a negative pressure device that creates a vortex between the BUG and the hull. It crawls on the hull surface and performs frequent grooming (light cleaning of fouling films). Sensors provide obstacle avoidance, path cleaning, and navigational capabilities. A fluorometer lets the robot detect biofilm and then it uses rotary brushes or water-jets to scrub the fouling film off [6].

Similar efforts to develop hull cleaning robots is being done by Keelcrab - Fig. 9. The product I-keelcrab is semi automatic robot fitted with ip68 high-resolution camera and can be guided by smartphone or tablet. Keelcrab-one is an underwater robot, which can be controlled by a wired remote control with live video feed [6].

Another example is MARC: Magnetic Autonomous Robotic Crawler - Fig. 10 [7]. As published by the authors [7] the MARC actuation system is basically constituted by a couple of magnetic tracks, actuated by an electrical motor coupled to a gear-head through a suitable mechanical interface. The magnets are lodged in dedicated housing connected to a chain to constitute a track.

Fig. 9 *Keelcrab hull cleaning robot*

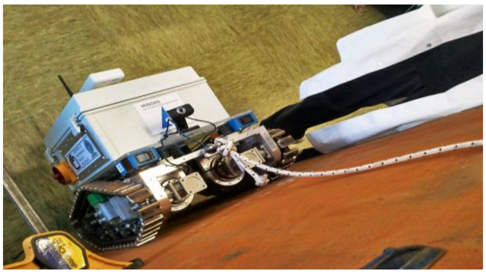

Fig. 10 *MARC final release, during vertical climbing test*

2.2 "ARMUS" underwater hull observation system

The robot was created under the leadership of academician Stefan Vodenicharov - leading Bulgarian security and defense scientist and professor Kiril Stoychev. The chief designers of the robot are Professor Dr. Daniel Bratanov and Dr. Rumyana Mihaylova. Participants in the development of ARMUS are also Captain NAVY Valentin Naydenov Retired Dipl.Engineer and his colleagues from the group of Varna with a special contribution to the mechanical work of the different elements.

The second generation of the ARMUS robot – Fig 11 a,b [8] is a designed in a way to be able to stay unlimited time underwater and to work on both sides (external and internal like cargo holders) of the ship's hull. The robot overall weight is 35 kg. and the attraction force of the tracks is 672 kg., doubled from the first generation. The robot uses a different approach from the first version. It is connected to the ship by a cable that supplies the robot with current between 110 V and 220 V. The same cable is used for the communication and control of the robot. The length of the cable can be up to 200 meters.

Fig. 11 *a Second generation ARMUS robot designed to work both underwater and on "dry" iron surface - top view*

Fig. 11 *a Second generation ARMUS robot - front view*

The track system of the robot uses a two wheels type suspension without the use of extra support wheels. This type of suspension guarantee the successful maneuverability of the robot on a dry and wet surface and at the same time does not allow the robot to lose its attraction force and to fall down from the inspected surface. The good attraction between the tracks and the iron surface gives the robot the ability to overcome different obstacles even when it is climbing the walls of the cargo holder or the underwater part of the hull. The schematics of the robot submerse system is given on Fig. 12.

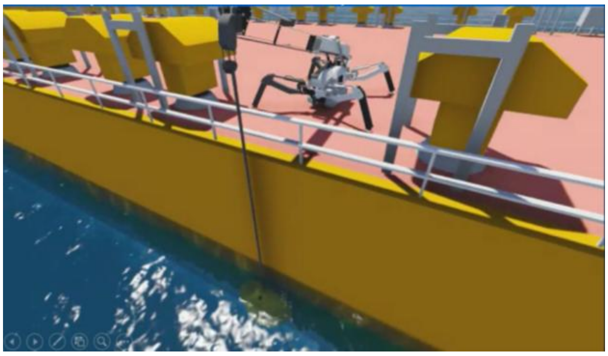

Fig. 12 *ARMUS submerse system*

The robot is controlled trough a specific graphical user interface. The control system consists of two main parts – remote control unit and onboard control unit. The onboard control unit is a computer linked to a series of controllers that are used for the control of the motors, the communication and the observation systems. The robot generally carry one pair of cameras – a high resolution observation camera and a secondary rear camera. The robot can carry also a set of scanning sensors depending on the particular needs of the customer and the type of observation that is necessary to perform. The engines are powered by AC – DC convertors. The second generation of ARMUS has a unique design of the suspension as the motors and the gearboxes of each track are mounted outside the sealed area of the robot body. Each motor is placed separately in a sealed chamber and the torque is transmitted to the track leading wheel by an open type clutch. The use of simple DC motors allows the robot motion even the motor chamber is flooded. The motor drivers are designed in a way to work even if the motor is in a short connection. This will help the operator to control the evacuation of the robot from the water in case of decompression of any robot's seal.

An important issue of the control system is that the graphical user interface of the control is designed to be user friendly and does not require a specific skills of the user in order to deal with the robot control. The control system has its internal procedures that prevent the operator of giving tasks that can cause a damage or malfunction of the robot.

Another advantage of ARMUS is that it can stay in hibernation as long as necessary. The system is of the type plug and play. The moment ARMUS control unit is plugged to the power supply of the ship and the connection cable of the robot is plugged to the control unit ARMUS is ready for action. The system for observation of the hull of large vessels is designed to search and identify limpet objects like naval mines, improvised explosives or contraband traffic attached to the underwater hull of the ship. It is able to perform tasks under various weather conditions during the ship motion.

CONCLUSION

The hydroacoustic buoy from the "SCIAERHAB" system, is developed by a Bulgarian company, with potential for use in different in structure and content objectives and tasks of the security and protection systems for port infrastructures. The buoy is a reliable mean for collection and transfer of information needed to respond teams for real time decision-making. It is made of stainless steel with subsequent chemical treatments of the metal, which protect it from fouling with marine organisms and from there allow it to be used for a long time in marine environment. It can be positioned to up to 200 meters deep and located a few tens of kilometers away from the land. The functions that buoy has for the information exchange with other elements of the security and protection system enable system operators to assess potential threats in a timely and objective manner, while planning adequate future actions, depending on the situation.

On other hand, the ARMUS underwater hull observation system is the only one known available at the moment robot capable to travel attracted to the ship surface both under the water and on the "dry" ship body. ARMUS is the ideal tool for fast and reliable ship observation in order to perform hull management. Its ability to stay underwater as long as necessary and more important to perform its tasks during the ship motion makes ARMUS a desired tool for security measures. The use of ARMUS is organized in natural manner and does not require specific skills from the personnel. The complete system is designed in a way to be durable and easy for maintenance. All materials used are corrosion free and resistant to aggressive and hazardous environment.

Working together in integrated systems for security and protection of port infrastructures, these two systems are able to increase their reliability and resilience in many extreme and complex situations, requiring the timely receipt and processing of the obtained data for the purposes of making adequate management decisions.

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