

SIRENA: Autonomous Integrated System for Naval Recognition and Exploration

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Abstract – This article outlines the initiative of some students from the Polytechnic University of Cartagena to create an AUV (Autonomous Underwater Vehicle) which will be powered by solar energy. The idea stems from the awareness of the tactical and economic difficulties involved in the deployment and withdrawal of large AUVs, as well as the current limited operability of such devices. SIRENA attempts to solve these problems, providing military and/or civilian research units with a system capable of performing for prolonged periods without direct human intervention and under adverse conditions. SIRENA is a project carried out exclusively by students with the purpose of exploit their individual potential and use the knowledge acquired at university.

Keywords – AUV (Autonomous Underwater Vehicle), ROV (Remotely Operated Vehicle)

I. INTRODUCTION.

Nowadays, carrying out underwater survey, mine search or fixing underwater pipes with an AUV or a ROV requires the use of a ship to move them into the place to do the task. Because of that there are necessary a lot of resources and human and material goods are endangered. In addition, when AUV is working the ship has to be constantly near it because of the limited autonomy that this kind of vehicles has. This reduces the efficiency of the operation and increase the total cost of the task. SIRENA changes that. On the one hand, SIRENA has a propulsion system that ensures reach medium-high velocities, with that, it is possible to travel long distance shortly. On the other hand, with the inclusion of the photovoltaic system, long travels doesn't suppose a decrease in the energetic autonomy. In low battery situations SIRENA will be able to surface and charge the batteries. All of this ensures that SIRENA has a great operational autonomy.

II. STRUCTURE

SIRENA has been divided into two different hulls: the resistant hull and the external one.

A. Resistant hull

This is the one which will contain the main electronic systems. This hull is being designed so as to resist an equivalent pressure of 500 meters of water column, with a security coefficient of 2.5. The design and study of this hull is following an evolutionary process, starting from elasticity theory and materials resistance, followed by rule design and finally CAD design and a Finite Elements Method analysis.



Fig 1. Resistant hull

Elasticity theory and materials resistance analysis turns truly complex when the hull geometry is not elementary, so variations in the design are complicated. As an alternative design, it was decided to do it according to ABS' Rules for Construction and Classification "Underwater Vehicles, Systems and Hyperbaric facilities, 2012" [1]. The main requirement established was the structural resistance at a depth of 500 meters with a security coefficient of 2.5, as stated previously. This requirement should be checked for the next types of structural failure: stress limits the yield pressure, stiffener tripping, local buckling and general instability.

B. External hull

The external hull's main purpose is to be the solar panels support, besides it will provide protection against collisions to the rest of the AUV. Systems which must be in touch with sea water will be placed between the external hull and the resistant one. This hull will be constructed in a combination of composites.



Fig 2. External hull

In order to minimize engine power needed to achieve higher speeds, the external hull has been hydrodynamically optimized subdividing it into three parts: a cylindrical central body and elliptical domes for bow and stern zones, so as to ensure a correct flow to the propeller. One of the methods being used to design the external hull's shapes is based on Larson's works [2], who included cylindrical zones between original caps according to the sixth degree polynomial.

$$y^2 = A_1x + A_2x^2 + A_3x^3 + A_4x^4 + A_5x^5 + A_6x^6$$

From these terms it can be obtained the following equation:

$$y^2 = 2r_0 \cdot R_0(x) + 2r_1 \cdot R_1(x) + Cp \cdot P(x) + Q(x)$$

III. PROPULSION AND MANEUVERABILITY

The propulsion system consists of a DC electric motor and a fixed pitch propeller. This system has been designed so that a maximum speed of 10 Knt submerged and 3 Knt. on surface are achieved. This specific speed range was determined with operability as the main goal. With a speed of 10 Knt, SIRENA would be able to sail up to 12 hours submerged without recharging, covering up to 220 Km, i.e. 120 miles, during this period of time.

In terms of the maneuverability system, it has rudders and elevators located fore of the propeller.

IV. PHOTOVOLTAIC SYSTEM

The solar panels are attached to the outer hull. They are operated through a hydraulic system. While submerged, panels are brought together onto the sides of the cylindrical body so that when they are completely folded, the shape of SIRENA is completely cylindrical with elliptical domes. In contrast, when SIRENA is sailing afloat and the solar panels are deployed, they lean on the water, adopting a shape similar to that of a trimaran.

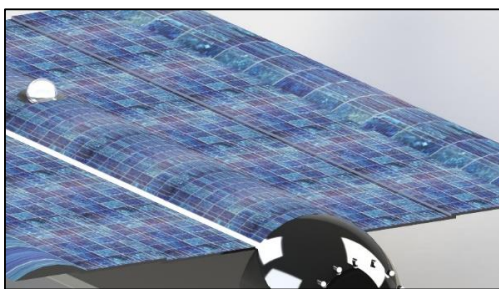


Fig. 2. Solar panels

V. PERISCOPE

The Periscope is another novelty added. It houses a rotary chamber and different communication antennae. This system allows for data transmission without emerging and is thus suitable for military missions in which it is necessary to remain undetected.

VI. ELECTRONIC SYSTEMS

The development of an AUV comprises a huge amount of devices and electronic systems inside. As regards as it is an

unmanned vehicle it is very important that anything in the surroundings or the inside could be randomly. In order to cover that point, SIRENA is provided with such a great variety of sensors and systems in order to be able to monitoring everything which happens around.

Among the different devices that the submarine is provided it can find side-scanning sonars which allow to detect objects approaching by the sides and in the bottom. On the prow of the AUV there is a multibeam sonar, which is able to scan in 3D the sea bottom or any other object opposite it with stunning high resolution. Besides those systems it is provided with camcorders to film, either with infrared or assisted with LED lamps. These camcorders are in both prow and periscope. Needless to say that the submarine is full-equipped as regards as sensor systems to ensure a proper work and integrity (pressure, temperature, overloads...).

It is unavoidable to say that a complete navigation and communications system is required. Due to that SIRENA is equipped with bathymeter, Inertial Navigation System (INS), GPS, and D-GPS, DVS sensor. Furthermore it is able to establish communication with earth by Wi-Fi, GSM, Iridium, acoustic and inductive modems.

Although SIRENA is on the vanguard of the technology, there is something that makes it unique, something that is a turning point as regards as submarine navigation, the solar power system. Thanks to it, not only is it completely efficient but also can work just emerging to charge its batteries of up to 15 kWh. The solar panels are assembled in a quite novel retractable system which simulates bird wings. These wings are unfolded in order to get a maximum usable area when is on the sea surface, whereas they are folded under water to reduce forward move resistance. Providing a usable area of 10 m² when they are unfolded, this AUV can get up to 1 kWh/h in best conditions. In other words, thanks to this SIRENA has an autonomy almost unlimited. However, if it have to specify a certain time of submerged work, it can reach up to 24 hours of uninterrupted work. That is to say, SIRENA is nowadays on the top of current commercial AUVs.

The Electronic system can be broken down in several subsystems.

1. Energy system. Consisting of solar panels, regulators and batteries.
2. Control system. It incorporates a main CPU and two secondary ones, plus a backup.
3. Self-monitoring and self-protection system. It includes all sensors that inform on indoor and outside weather conditions, as well as the key electrical signal variables.
4. Navigation system. Consisting of a GPS, D-GPS, INS and DVL.
5. Communications system. WIFI, GSM, RF, and Iridium communications have been incorporated.

6. Interaction system, consisting of passive sonar, active sonar and sidescan sonar.

7. Visual system. This system consists of the bow camera, the periscope camera and the 3D multibeam sonar.

MISSIONS

This first version of SIRENA has focused on the military sector. Further development may lead SIRENA to carry out tasks in the civil sector or within the field of oceanographic research. Some of the missions that SIRENA can perform, are:

1. Mine clearance missions.
2. Surveillance missions.
3. Escort missions.
4. Search missions.

FUTURE OBJECTIVES

Right now, SIRENA is a project that has to grow a lot. This prototype aims to prove that this kind of technology works properly and if there was a constant development of this systems, there could achieve great progress in the maritime industry. The following objectives are:

1. Work and exchange information in groups.
2. Modular adaptation.
3. OTAN dimensions adaptation.

REFERENCES

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[2] Pedro Sosa Marcelo, Cap 6. Formas y Resistencia. Parte 6. Anexo A, 03-2007

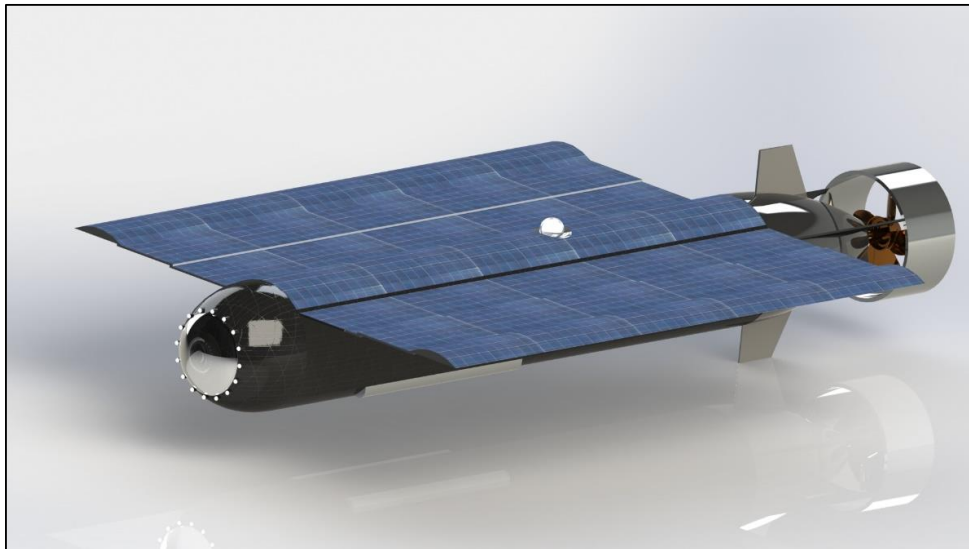


Fig 3. SIRENA