Unmanned Surface Vessel for Marine Data Acquisition

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Abstract. This paper brings to the fore, the construction of a remote controlled naval platform, without crew on board, and its possibilities to transmit or record data in inaccessible areas or in marine areas in which human life would be endangered. Although these unmanned platforms are not a novelty, they being used mostly for military, the solution presented is a Romanian premiere, similar to international standards, but at much lower cost, with the advantage that certain environmental action is totally insignificant. It was presented only a range of applications (video data, forecasts and submarines), the platform built in the “Mircea cel Batran” Naval Academy, allowing many improvements based on equipment that can be mounted on board.

1. Introduction

Depending on the objectives, many of the techniques and technologies that are currently used for marine survey, are causing irreversible damage to the natural environment of the current ecosystems. Regarding at the use of USV (Unmanned Surface Vehicle) vehicles type, unmanned, remote controlled or guided on imposed routes, they have the advantage of the human absence, taking information that may be relevant as research data [1].

The remote-controlled vehicles have been built since 1940 and were used in military operations for demining marine areas. Unmanned vehicles have also been used for the environmental research, and for taking water samples after the release of the famous radioactive atomic bombs.

The main features of USV are:
• Autonomy: the ability to operate over a long period of time in order to extend the investigated area, this can be extended by using non-conventional energies.
• Reduced risk: avoiding endangering or loss of human lives and damage the picturesque of sea.
• Displacement: due to the small USV size this can slip easily through natural or artificial obstacles.
• Economy: low power consumption and reduced number of maintenance and operation team, assigns to USV an advantage in terms of human resource and energy costs.
• Profile: USV is operating at sea with low acoustic and electromagnetic signature, which represents a minor risk for the marine environment.
The most important feature of a USV is that the operator remains in a safe environment while the vehicle fulfils its mission in various environments with high risk, even hostile or inaccessible for the large ships.

The domains serviced by USV's can be classified as [2]:

1. Education and Science, with an emphasis on education (applications and practice), research and development, oceanography (marine research and data transmission, collecting water samples and biological), ecology, etc.

2. Emergency services, related to police operations (search for evidence, observation of interest, monitoring of polluted areas), border police operations (observation, search and rescue, inspection of unidentified objects etc.).

3. Military, the main missions are: research and observation of navigation districts; action against marine mines (the rapid establishment of a safe transit zone for the fleet by surveying the area and destruction of possible mines with missiles and mines launched from USV), antiterrorism (the capacity to observe, query and even destroy the unidentified boats), antisubmarine (USV have performing equipment on board radiolocation and hydrolocation able to discover and track submarines etc.).

Existing autonomous vehicle models are developed in the presence, as follows:
- Autonomous surface vehicle Cat C-4 (Figure 1a)-developed to take samples of water and assess the aquatic environment on coastal zones [3].
- Autonomous surface vehicle WAM-V (Figure 1b). It was built in 2013 by the Office of Naval Research USA and has been used by Google to map the coast waterfront of San Francisco. It can be mounted / dismounted in 7 parts of two people in less than 3 minutes [4].
- Autonomous surface vehicle Rafael Protector. The vehicle is also part of a group of autonomous vehicles in the US Navy (Figure 1c), with the difference that is larger and is intended to be included in some combat missions. Rafael Protector USV is a high-speed craft, built with a rigid and resistant body. It is a modular vehicle that has on board weapons system and can be adapted to different types of missions such as: surveillance, reconnaissance, antiterrorism and electronic warfare [5].

2. Elements of design for Marine Engineering Faculty - USV 01
Table The design elements that give mission and performance requirements of USV were generated by potential product capabilities. This elements, also, provides the basis for the design and construction of on board systems. The requirements of the mission provide first information about tasks that will be
fulfilled launching the USV. Performance requirements are derived from USV’s specific missions and establish the capabilities for meeting the requirements envisaged (speed, maneuverability, endurance, autonomy, etc.). These requirements are the basis of vehicle characteristics development and associated systems, while being essential elements for performing the analysis of cost-effectiveness and that must allow further development with knowledge evolution in the field.

To obtain these items, we conducted an experimental model that we tested by various methods of transmitting data and various modern integrated systems related to propulsion and maneuverability.

![Figure 2 Marine Engineering Faculty-USV 01](image)

The experimental model is a representative for an autonomous vehicle surface, in order to investigate experiment and demonstrate the possibility of building a USV Class X (Figure 2). Design and construction of the prototype was done in the Research Laboratory of the Faculty of Marine Engineering in the Naval Academy in Constanta, name Marine Engineering Faculty-USV 01.

USV’s body was designed as a hydrodynamic body, composed of a lightweight material, namely glass fiber reinforced with aluminum structure. In order to achieve this body it was necessary to use a very light material for reduction of the total mass and obtaining a positive value of buoyancy, also, taking into account the weight of all equipment necessary to accomplish missions. The design of the body that revealed USV’s capabilities was established as catamaran boat type with two identical immersed bodies, called "twin-hulls" houses mounted on basic structure represented by a rigid aluminum frame. The choice of the following body were taken into account the benefits, specific to "twin-hulls" bodies, as follows:

- the catamaran can sail in shallow waters due to smaller draft, the displacement of USV being distributed between the two hulls;
- space for equipment and renewable energy systems is more generous compared to other types of boats;
- has a high stability against the waves from all directions, very difficult sunk;
- aerodynamic and hydrodynamic shape lead to low drag resistance, thus the USV can reach great speeds relative to another type of boat at the same size.
The main element to be considered for body design was the study of "optimum distance" between immersed hulls, because this type of structure can create an own waves system, affecting structural strength during operation and can also considerably increase the advancing resistance of the vessel.

Technical features designed for generic platform, are:

- Length: 4[m];
- Body weight: 60 [kg];
- Propelling force: two electric motors- 2 x 18[daN];
- Displacement- 130 [kg], max 200 [kg];
- Autonomy – 3 h;
- Draught - 0.11 [m];

The starting point in building the catamaran was made up of two kayak bodies fiberglass profiled, representing hull type 'twin-hull' which are secured by rigid structure of aluminum bars.

The stability calculations of USV's it was done by calculation, which showed that this type of platform is an optimal solution for autonomous naval USV 01 FIM platform. The diagram on the right hull catamaran floating in calm water is shown in Figure 3. The straight hull diagram of catamaran floating, for calm waters, was based on the values calculated in the Autoship program.

The sizes in the diagram have the following meanings:

- Awj - surface of floating area;
- XFj- the abscissa of the geometric center of the floating surface;
- Ilj– momentum of longitudinal inertia;
- Itj - momentum of transverse inertia;
- CWj – coefficient of float surface.

![Figure 3. The diagram on the right hull catamaran floating in calm water](image)

The straight hull diagram and stability calculation of the ship have demonstrate the special nautical qualities, proving that it can safely sail even under unfavorable condition.

The total displacement of the vessel:

\[ \Delta = \Delta_{ng} + \sum m_i = 130 \text{[kg]} \]  \hspace{1cm} (1)
Where: $\Delta_{ng}$ is displacement of the vessel without load and $\sum m_i$ is embarked masses of the vessel.

Using $\rho$ – sea water density, it was calculated $V$ – hulls, and from straight hull diagram was established the vessel draft at this volume of hulls, following to extract $II$ and $KB$ (the center line of straight hulls) terms for appropriate floating.

$$V = \frac{\Delta}{\rho} = 126000 \text{ [cm}^3\text{]}$$ \hspace{1cm} (2)

$$KB = 6 \text{ [cm]}$$

$$II_{(cat)} = 402000 \text{ [cm}^4\text{]}$$

Centre of gravity is calculated using the formula:

$$KG = \frac{KG' \cdot \Delta_{ng} + \sum_{i=1}^{n} m_i \cdot z_i}{\Delta_{ng} + \sum_{i=1}^{n} m_i} = 2.6 \text{ [cm]}$$ \hspace{1cm} (3)

For calculating the center of gravity quota, it was specified the following size:

- metacentric radius cross:

$$BM_T = \frac{II}{V} = 3.19 \text{ [cm]}$$ \hspace{1cm} (4)

- transverse metacenter height:

$$KM_T = BM_T + KB = 9.19 \text{ [cm]}$$ \hspace{1cm} (5)

- transverse metacentric height:

$$GM_T = KM_T - KG = BM_T + KB - KG = 6.59 \text{ [cm]}$$ \hspace{1cm} (6)

Reports between dimensions:

- The ratio between length $L$ and theoretical width $B$ is: $L / B = 1.8$. This value corresponds to high stability and low speed for single hull vessel, for “twin hulls” catamaran type we have a good speed compared to boats of the same size.

- The theoretical ratio of the height $H$ and draft $d$ is: $H / d = 22.8$. This report demonstrates that the USV has a high stability.

- The ratio of the theoretical length $L$ and the height $H$ is: $L / H = 2.5$. This value is indicative for a high longitudinal strength.

In conclusion, this size ratios demonstrates the main advantages of catamaran type vessel: stability, ability to keep the sea and good maneuverability. The practical achievement of such a body is shown in **Figure 4**.

![Figure 4. Catamaran body](image)
The propulsion system is intended to move the vehicle forward and backward. Governance body is also included in this scheme and propulsion government belong to the same system, type AZIPOD (azimuthal thrusters).

Under this system are designed to drive contained the following equipment:

- two electric motors Minn Kota Endura C2 New;
- two brushless DC Drive Controller;
- two Futaba receiver 6-J;

The chosen electric motor type was Minn Kota Endura C2, an improved version of the model C1, which develops a thrust of up to 18.1 [kg], the electric power being achieved from 12 [V] alkaline accumulators. The energy autonomy based on chosen accumulators is about 3 hours at a speed of 4 [Nd].

Brushless DC (Drive Controller) is an electronic circuit used in order to vary the speed of the electric motor and to act as a dynamic brake.

Regardless of the used type, a DC, generally, interprets control information not as mechanical movement, such in the case of an actuator, but rather in a way that varies the switching speed of field effect transistors (FET). This allows a variation much smoother and more precise of the motor speed in a more efficient manner than the mechanical type with resistive coil.

The propulsion command is done by the command post of the craft and serves to transmit commands to the thrusters and actuators (Figure 5). The link from the command post to craft, which is designed to transmit commands to the thrusters and actuators vehicle is running with a portable transmitter type Futaba 6EX. The propulsion system has installed a Futaba receiver (Figure 5) for receiving radio signals transmitted by the console when USV is running in manual mode.

Futaba 6EX is a very simple but very powerful remote control of motors and actuators and has both transmitter and receiver own. The operating frequency is programmable from 2.4 [GHz] to 6 channels. The range of the system can be reached in good weather conditions with no obstacles between antennas to 3-4 [km].

![Figure 5. The propulsion command](image)

3. Sensors and data acquisition equipment

Following the analysis, which it was based on data volume and speed transmission, it was concluded that the best connection for data transmission is the radio link in 2.4 [GHz] frequency spectrum (figure 6).

A critical factor limiting range of this connection is closely related to EIRP parameter (Equivalent Isotropically Radiated Power) - radiated power density of an ideal lossless antenna in the direction of maximum gain. Our legislation limits the value of EIRP, on amateurs' regime, at 100 [mW] equivalent to 20 [dBd] maximum gain.

The chosen equipment for making the radio link between the vehicle and the shore station is METAL 2SHPn router that serves to transmit all the data collected by sensors at the post command.
This wireless device, waterproof, operates in 2.4\,[GHz] frequency. In junction with a very large gain antenna, the working distance can reach distances of 30-40\,[km]. We use a 6\,[dBi] antenna which will give a range of 6-7\,[km] to meet our operational requirements.

In accordance with the mission that USV have to perform the autonomous platform was equipped with various equipment and sensors, as follows:

- **Camcorders.** The video received from USV’s board is captured using two cameras. Main camera that aims mainly carrying out the reconnaissance and surveillance of the vehicle and has a 3-axis freedom of motion, being able to focus on a specific object image. The secondary camera has two axes freedom of motion and the main role is to provide information about navigation status and any obstacles that vehicle encounters on his way.

- **Side Scan Sonar.** Sonar equipment which gives the underwater images, near the vehicle. It aims to discover navigation hazards and to discover the potential targets for military or civilian parts, like: marine mine, enemy divers, underwater vehicles or small groups of fish. The vehicle is equipped with a Raymarine Wi-Fish sonar type with adobe Down Vision. This small sonar is used more fisheries, but has a very good application on our missions and requirements

- **Weather Station** WS-1440-IP OBSERVER. USV-fitted weather station is a small station sizes, powered by three rechargeable AAA batteries, using solar energy. This station has the capability to measure 15 different parameters, of which the most important are: temperature, moisture, atmospheric pressure, wind direction, wind speed, solar radiation, etc.

- **GPS – UBX-G7020 module.** The receiver onboard autonomous vehicle is the MOD-GPS type. The device which receives both the GPS satellite system and the GLONASS provides a precision of 10-15m. The receiver is integrated into the microprocessor on board that transmits by the radio link the received position to be displayed on the display from the shore command station.

  The current position will be displayed on the ENC (Electronic Nautical Chart) so that the operator will have a clear picture about the position, direction and speed of a moving vehicle.
4. Conclusion
The remote-controlled surface vehicles represents a very good solution with a very low pollution impact on the environment and marine picturesque. Beginning with the coming years, we have faith that we have to diversify research capabilities for USV. Autonomous surface vehicles will provide additional information, providing better surveillance especially on the open sea, where the loss of human life is unacceptable, but also inland. Through its very small draft, it can operate in areas where it is impossible to send a manned craft. It can also be used in emergency situations such as monitoring the areas contaminated by radiological, chemical or nuclear agents. Another advantage is the short time for operating compared to a manned ship, including their increased speed and maneuverability.

This autonomous platform may have an important contribution for maintaining and carrying out the daily tasks, such as monitoring compliance with maritime laws, collect information and data necessary to identify vessels with illegal activities (piracy, drug traffic, illegal immigration), fisheries and pollution monitoring potential for unattended areas. The many type of mission it can perform, indicate multiple ways of product development. In this respect, existing equipment may also include additionally: video cameras (standard infrared thermal imagers), navigation lights, sensors, radar, sonar, and different types of weapons, both lethal and non-lethal.

The main difficulty faced by USV developers is a challenging physical environment. The vehicle is subjected to the influence of sea currents, wind, waves, temperature and corrosion. Communications are in some cases intermittent and data from sensors are provides with considerable delay. Deployment, operation and recovery of the vehicle are time consuming and expensive, and its dynamic control is a challenge for the operator. Also propulsion is expensive and sometimes slow and operability period is limited by environmental conditions.

Regarding the potential risk in terms of marine environment pollution this is virtually nonexistent, USV’s operation is done without been resented by marine surface or underwater ecosystems.

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