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A Multiporpouse Amphibious Rover (MAR) as Platform in Archaeological Field

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Abstract **– In recent years, the use of drones in the archaeological field has grown considerably. This growth comes from the possibility of using these Unmanned Aerial Vehicles (UAV) for topographic surveys, detect the presence of buried archaeological remains and monitoring the conditions of buildings or monuments. The objective of the study will concern the description of MAR (Multipurpose Amphibious Rover) vehicle with the physical principle that regulates its functioning and the possible applications in the archaeological field.**

I. INTRODUCTION

One of the most recent and significant innovations in the archaeological field was to introduce remote sensing as an investigation tool. Precisely remote sensing can be performed by using static systems (i.e. wireless sensor network) or dynamic systems as satellites, unmanned aerial vehicles (UAVs), terrestrial or underwater drones. Static system are typically used to measure environmental parameters, which can provide raw information on possible critical situations in which an archaeological site could fallen [1-3]. Between the dynamic systems, flying systems as satellites and UAVs provide topographical information and detect archaeological ruins monitoring the state of conservation of buildings and monuments. The latest allowing checking the site not only from above the surface but also at the height of the monument and at close range. For their intrinsic characteristics of ease of use, affordability, availability and the ability to change the payload, recently, archaeologists have shown a great interest in UAVs as highlighted by recent publications [4-12] where Fixed-wing [13] and multi-rotor drones [14,15] have become the most used UAV platforms.

Among the most common multi-rotor drones, we find the tricopter, quadcopter, hexacopter and octocopter. In particular, their advantage is the manoeuvrability; in fact, they can be used in several environments. Unfortunately, their most significant limitation is the flight time, usually 30 minutes, and this allows them to map small areas.

Fixed-wing drones, unlike the Multi-Rotor, do not consume large amounts of energy, thanks to the lift generated by the wings. This particular makes fixed wing drones an optimal choice for activities that require the coverage of large areas, such as agricultural surveys or the mapping of large archaeological sites. However, fixed-wing drones unlike Multi-Rotor drones, tend to be significantly more expensive, more difficult to transport, but mostly have low manoeuvrability.

An example of application of these unmanned aircraft is shown in [16] where it was possible to reconstruct the Temple of Tholos in Delphi using a manual helicopter. Also in [17] by using a mini helicopter and a mini aeroplane have been acquired low altitude aerial images while in [18] through the use of a microdrones platform have been taken aerial photographs of archaeological remains located in the archaeological area of Tuekta, Russia.

Recently, in the archaeological field the use of rovers, terrestrial drones equipped with wheels or tracks is becoming more and more popular, as they can be used in different environments [19].

Contrariwise, due to their weight, these vehicles cannot be used in all types of cultural sites; an example is given by mosaics whose tiles must not be subjected to mechanical stress, such as that generated by the wheels or tracks of the rover.

In recent years, underwater archeology has seen an increase in the use of AUVs (Autonomous Underwater vehicles) whose purpose is to help the search for underwater archaeological remains [20-22]. The advantages of using these AUVs compared to large ships mainly concern the costs, the possibility of carrying out inspections even in shallow waters, such as ports and coastal areas [23].

In these last years, for underwater archeological activities have been developed and tested crawler rovers, which can perform several interventions walking directly on the seafloor. Already in the past, crawler rovers had been used for planetary missions to inspect both the moon and mars surface.

An example of crawler rover used for archeological and scientific activities is reported in [24]; it can operate at a depth of 100 meters being controlled by a remote control cable from the beach or boat.

The purpose of this study is to present a new concept of amphibious drone (Multipurpose Amphibious Rover - MAR), which, in a complementary way to the other types, can contribute to enrich the information coming from a survey campaign allowing the archaeologist to have a more exhaustive overview of the area to be investigated.

II. MULTIPURPOSE AMPHIBIOUS ROVER

The MAR vehicle (Multipurpose Amphibious Rover), developed by Se.Te.L, a company specialized in Integrated Logistic Support Engineering, in collaboration with the Electric and Electronic Measurement Laboratory (MEALab) or "Roma Tre" University, is an amphibious system composed by a platform, the rover itself and a ground station necessary to pilot it remotely (see Fig. 1).

Fig. 1. Multipurpose Amphibious Rover.

This vehicle moves exploiting the physical principle of the pendulum. In detail, this pendulum is represented by elements called cradles placed inside the wheels. The outer wheels can act as traction system, sealed container of the payload and floating support. The internal volume of the wheels, of about 500 dm^3, with a gross weight of 120 kg allows the vehicle to have a good buoyancy margin in water.

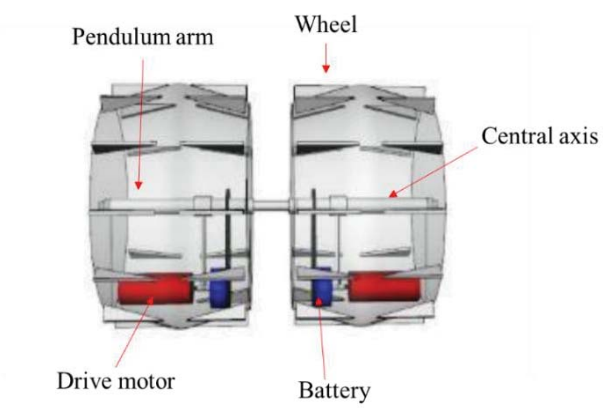

Fig. 2: Drive motor and battery pack contribute to the thrust.

In this vehicle, typically negative elements such as weight of the engines, transmission and batteries, become positive elements because they contribute to the thrust. In Fig. 2 are shown some elements of the rover.

Another key element of the vehicle is its Low Centre of Gravity, which makes it very stable, so low that, in the event of a rollover, it can automatically return to its original position (see Fig. 3).

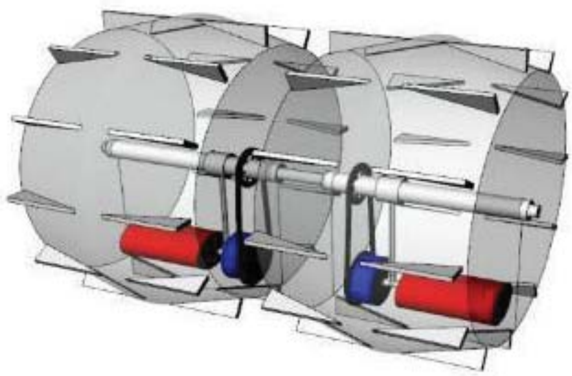

Fig. 3: Batteries and motors generate a low centre of gravity.

This is due to the cradles, which house motors, batteries and part of the payload (see Fig. 4). The cradles, made of polyethylene, are constrained to the central axis and are placed inside the wheel near the ground. Concentrating the transported mass in the lower part of the drone, the cradles guarantee high stability to the drone itself.

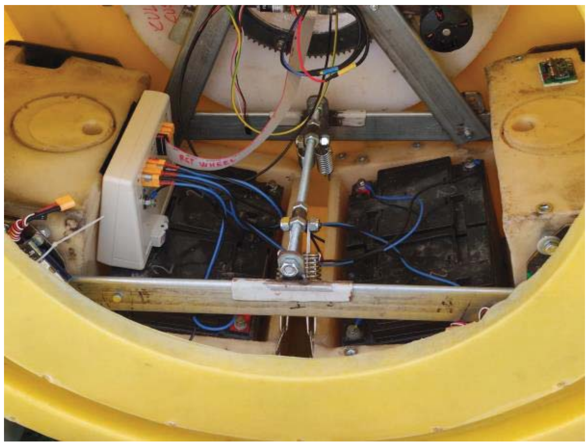

Fig. 4: Particular of internal part of the wheel where the cradle is partially shown.

This vehicle can carry sensors, any liquids and Personal Computer in the central body or in the cradles. The outer wheels made in polyethylene material are very light and resistant to chemicals, acids, alkalis and petrol.

These two wheels were made through the rotomoulding technique. The principle of rotational molding is shown in Fig. 5.

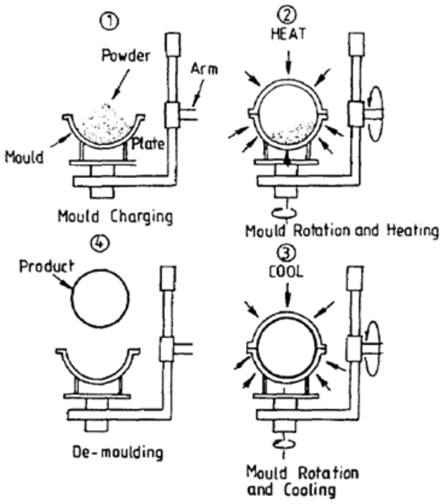

Fig. 5: Rotation moulding process.

The polymer inserted in the form of powder is placed inside a metal mould. Subsequently this is slowly rotated so that the internal walls of the mould come into contact with the polymer powder. Once the mould is filled and rotated slowly, it is placed in an oven and heated with temperatures between 200 and 250 Celsius degrees. Once the plastic has adhered to the mould, this latter is cooled with air jets so that the plastic solidifies. In this way, the mould can be opened thus obtaining the solidified product.

As just described, the rotomoulding technique is expanding and offers various advantages both from an economic and a technical point of view.

The two external wheels are connected between them by a central axis, whose function is to ensure the independent rotation of the three bodies; both the two external wheels and the central body must be able to move independently.

The movement of the drone is triggered by a pendulum system. The importance of this element derives from the fact that it must trigger the torque necessary to make move the vehicle. Each pendulum assy is equipped with four internal drive wheels for the cradles which have the function to reduce the resistance to advancement and therefore to have a lower consumption (see Fig. 6).

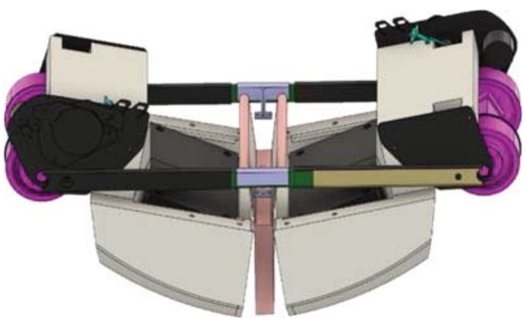

Fig. 6: cradle composed by two semi-motor cradles

The movement of the cradle is triggered by two elements called boomerangs placed on the back of the cradles; the so-called central assy showed in red (see Fig. 7) have the purpose to keep both the cradle in a central position and to make move the cradle inside the wheel.

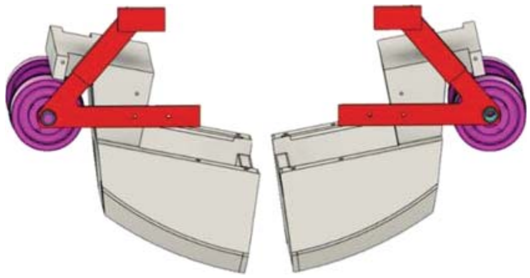

Fig. 7: Central assy.

The first tests carried out in field have highlighted the need to equip the external wheels by rubber covers (Fig. 7) where their aim is both to protect the polyethylene from abrasion and allow at the same time the rover to move in slippery environments, increasing its grip. This rubber, which represents a second prototype, will allow the vehicle to move in several environments like mud, snow and lagoon.

Fig. 8: Second prototype of tire assy.

The outer wheels can be equipped with thrusting organs, such as paddles that allow the rover to get amphibious characteristics as shown in Fig. 9.

Fig. 9: MAR equipped with thrusting devices and tested at Sicilian beaches.

As shown in Fig. 10, this vehicle has been tested in shallow water showing us how it can even move in this environment.

Fig. 10: MAR tested in shallow water.

By focusing on underwater archaeology, as this vehicle can float it can be used as a platform, which could host specific sensors currently employed for underwater archaeology operations. Among these, the most common are: the echo sounder which, in addition to returning a map of the seabed, also provides us with depth; the Side scan sonar which can be used in a complementary way to the echo sounder and finally the magnetometer that, based on the irregularities of the Earth's magnetic field caused by objects that have their own magnetism, is able to detect objects such as terracotta or wrecks.

III. CONCLUSION

This paper focuses its attention on the presentation of a new kind of rover called Multipurpose Amphibious Rover (MAR) and on the possibility of using it in archaeological operations.

Its characteristics in terms of low weight, high stability and ability of buoyancy on water make it suitable for several activities as monitoring the conservation of archaeological buildings and artefacts by using specific sensors like multispectral, hyperspectral, thermal, laser scanner or acoustic sensors.

The internal volume available inside rover could host devices such as geo radar to discover buried archaeological remains or a laser scanner evaluating the state of the artefacts brought to light and create 3D models useful for planning restoration interventions.

In this last period, we are seeing a growing increase in unmanned vehicles for underwater archaeology where the goal is to collect information on the possible identification of archaeological evidence on the seabed.

About that, MAR is able to both float, above all in shallow water such as ports, coasts but also in rivers and lakes, and carry at the same time sensors becoming, therefore, useful to underwater archaeological operations.

MAR, if compared to a classic crawler rover, cannot carry out operations in depth and to walk on the seafloor thus resulting completely complementary relative to each other. MAR has been conceived to be remotely driven from a ground station while, typically, a crawler rover is controlled by a cable.

Moreover, in the presence of any underwater archaeological remains in shallow water this vehicle being light would not cause damage both marine flora and submerged structures with respect to a crawler rover.

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