STUDY ON THE REALIZATION OF AN UNDETECTABLE MARINE DRONE AND ITS COMMAND-AND-CONTROL METHODS

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Abstract: INCDMTM Bucharest has a strong experience for more than 20 years in producing industrial manipulator arms, industrial robots, utilitarian robots, security robots and drones. Part of INCDMTM The CERMISO Centre (Research Centre for Intelligent Mechatronic Systems Used for Securing Objectives and Intervention) is composed by several laboratories dedicated to the research and development of flying and terrestrial drones.

INCDMTM have researchers with a vast expertise in robotics and drones being directly involved in the activity of the CERMISO Center (Research centre for intelligent mechatronic systems used for securing objectives and intervention) and CERTIM Center (The Research Center for Laser Measuring Technology). These are the premises that were the basis for the idea of expanding the study area of the CEMISO centre by adding the area of maritime drones to those already existing.

SC MDM Standard SRL, requested a feasibility study before starting a project for the effective realization of a maritime drone able to be controlled by an Artificial Intelligence. This study was to determine whether or not it is possible to achieve a viable experimental model, taking into account the existing facilities in INDMTM and SC MDM STANDARD SRL. The proposed drone was an Undetectable Marine Drone powered with Magnetohydrodynamic Engine controlled by Artificial Intelligence. The drone will have two operating modes, floating and submersible. In order to obtain an Undetectable Marine Drone it was necessary to equip it with a special engine without any moving element in order not to produce noise when in movement. Also, important and extremely challenging aspect of such a future project is to obtain a way to coherently control remotely a drone equipped with such an engine in order to be able to execute specific missions in areas where the surveillance and/or interventions of/in some objectives must be done in „*marine stealth mode*” (i.e. *invisibility mode*). In order to avoid both sonar type detectors (passive mode and active mode) the drone must not make any sound (to avoid passive sonar detection) and it must be capable to emulate a movement similar to that of a marine creature, usually fish (to avoid active sonar detection). The control of the drone becomes the obligatory prerogative of an artificial intelligence capable of simulating several cases and modes of movement depending on the possible detection conditions in the work area.

Keywords: Invisible-drones, Undetectable-drone, MHD-drone, Artificial intelligence.

1. Introduction

INCDMTM Bucharest has a strong experience for more than 20 years in producing industrial manipulator arms, industrial robots, utilitarian robots, security robots and drones. Part of INCDMTM The CERMISO Center (Research centre for intelligent mechatronic systems used for securing objectives and intervention) is composed by several laboratories dedicated to the research and development of flying and terrestrial drones. A strong collaboration with Group Renault had as a result a wide variety of line robots and automatization equipment already implemented into the production lines of Dacia Renault Pitesti. It can be mentioned: Production line robot with 6 inter operational checkpoints for DCV; Installation for control of band and twist of the rod assembled; Installation for checking air-air tightness of the engine sealing’s; Line robot for shock control of differential crown teeth’s; Automatic device for control of channels diameters of K Engine; Line robot control device (control deviations of form and position); SAM robot for testing carter engine tightness, line robot for control levels and diameters of machined cylinders; line device control for cross odds for Semella H4 DA Edison; various automatization of production lines posts; etc.

INCDMTM has researchers with a vast expertise in robotics and drones being directly involved in the activity of the CERMISO Center (Research centre for intelligent mechatronic systems used for securing objectives and intervention) and CERTIM Center (The Research Center for Laser Measuring Technology). These are the premises that were the basis for the idea of expanding the study area of the CEMISO centre by adding the area of maritime drones to those already existing.

It should also be mentioned SC MDM Standard SRL, which requested a feasibility study before starting a project for the effective realization of a maritime drone able to be controlled by an Artificial Intelligence. This study was to determine whether or not it is possible to achieve a viable experimental model, taking into account the existing facilities in INDMTM and SC MDM STANDARD SRL.

2. The Drone

So, the final version of the proposed drone was an **Undetectable Marine Drone powered** with **Magnetohydrodynamic Engine** controlled by **Artificial Intelligence**. The drone will have two operating modes, floating and submersible. In order to obtain an Undetectable Marine Drone it was necessary to equip it with a special engine without any moving element in order not to produce noise when in movement. The solution, not yet produced or studied in our country (some experiments seem to be signalled in USA, Japan and Russia), is the use of a Magnetohydrodynamic Engine. Also, important and extremely challenging aspect of such future project is to obtain a way to coherently control remotely a drone equipped with such an engine in order to be able to execute specific missions in areas where the surveillance and/or interventions of/in some objectives must be done in „*marine stealth mode*” (i.e. *invisibility mode*). In order to avoid both sonar type detectors (passive mode and active mode) the drone must not make any sound (to avoid passive sonar detection) and it must be capable to emulate a movement similar to that of a marine creature, usually fish (to avoid active sonar detection). The control of the drone becomes the obligatory prerogative of an artificial intelligence capable of simulating several cases and modes of movement depending on the possible detection conditions in the work area.

Magnetohydrodynamics (MHD, also magneto-fluid dynamics or hydromagnetics) is the study of the magnetic properties and behaviour of electrically conducting fluids. Examples of such magneto-fluids include plasmas, liquid metals, salt water, and electrolytes. The word "magneto-hydro-dynamics" is derived from *magneto* - meaning magnetic field, *hydro* - meaning water, and *dynamics* meaning movement.

The field of MHD was initiated by Hannes Alfvén, for which he received the Nobel Prize in Physics in 1970. The fundamental concept behind MHD is that magnetic fields can induce currents in a moving conductive fluid, which in turn polarizes the fluid and reciprocally changes the magnetic field itself.

By taking advantage of sea water’s electric characteristics, the electromagnetic propulsion of marine vehicles has been a subject of technical speculation and study for some years. The concept did not appear to hold much promise until the advent of the superconducting magnet.

Figure 1- Undetectable Marine Drone - Concept

With such a magnet, the power requirement for excitation is virtually absent, and the weight penalty of the magnet is drastically reduced. Also, today, much stronger magnetic field than those previously attainable can be realized so the idea of marine drones using Magnetohydrodynamic Engines is much more interesting although in the existing documentation there are no references regarding studies or attempts in this respect. It is for sure that in our days few moderns American, and Russian nuclear submarines have, as a secondary propulsion system, Magnetohydrodynamic Engines.

However, it is fair to predict that in certain naval applications where the importance of acoustic signature of a vehicle is outweighing other considerations, the MHD technology offers superior quietness because of its reduced mechanical moving parts.

In the consideration of duct-type internal MHD thrusters, the electric current and magnetic field in the sea water are normally arranged to be orthogonal to each other in the channel to provide an optimal Lorentz force. Sea water is being pumped in a straight active section of the channel. Immediately following that the sea water is pushed through a smooth nozzle that provides an adequate momentum thrust to makes the vehicle move. As shown in *Figure 2* an Magnetohydrodynamic Engine it is built around a duct section (cylindrical in the below example). There is a fixed magnetic field generated by two Magnets and two electrodes where potential difference is applied.

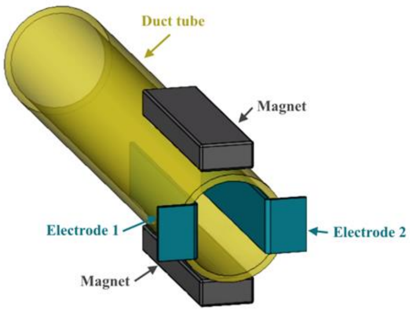

Figure 2 - Magnetohydrodynamic Engine (Schematic)

Similar with an electric motor, between the electrodes, an electric current (see *Figure 3*) is generated. The electric current is supplied by the electrodes from the top to the bottom, and the magnetic field is to be perpendicular to the current. The Lorentz force is directed to the left to push the sea water through the nozzle (*Figure 3*).

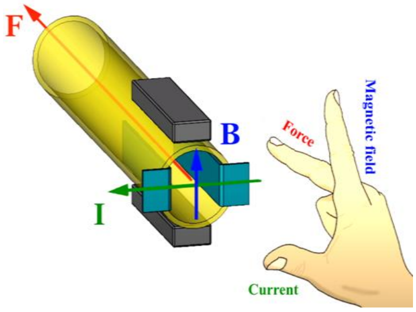

Figure 3 – Lorentz force push the engine forward similar to a classic jet engine (respect's the rule of the right hand)

The propulsion force is proportional with the conductivity of the liquid (in which the engine is submerged), the current value, the section of the duct tube and with the magnetic field intensity. Lot of others parameters are also to take into consideration, in order to increase the engine efficiency, as inner form of the duct tube, admission and evacuation nozzles, length of the engines, etc. The electric current is supplied by the electrodes from the top to the bottom, and the magnetic field is pointed so as to be perpendicular to the current. The Lorentz force is directed to the right to push the sea water through the nozzle. The net current flowing across the MHD channel between the electrodes is,

$$I = (V - ED)/R \tag{1}$$

where *D* is the electrode gap distance, *E* is the flow-induced electric field whose direction is anti-parallel to *I*, and *R* is the electric resistance of sea water in the channel. If the width and length of the electrodes are *W* and *L* respectively, then the resistance is,

$$R = D/\sigma * W * L \tag{2}$$

where σ is the electric conductivity of sea water ranging from 4 to 5/(Ohm*m). The first order magnetohydrodynamic approximations are then taken to assume only the induced electric field is significant, but not the induced magnetic field. Thus,

$$E = B * U_{in} \tag{3}$$

where U_{in} is the velocity of sea water in the channel. Defining the field induction efficiency to be,

$$\eta_{ind} = (E * D)\ /V = (B * U_{in} * D)\ /V \tag{4}$$

and the net current becomes,

$$I = ((1 - \eta_{ind})\ /\ \eta_{ind}) * \sigma * B * U_{in} * W * L \tag{5}$$

The total Lorentz force pushing the sea water in the channel is,

$$F_{em}=I * D * B=((1 - \eta_{ind})\ /\ \eta_{ind}) * \sigma * B^2 * U_{in} * D * W * L=((1 - \eta_{ind})\ /\ \eta_{ind}) * \sigma * B^2 * U_{in} * V_{ch} \tag{6}$$

where V_{ch} is the active volume of the channel. So, the mechanical power imparted on the sea water in the channel is,

$$P_w = F_{em} * U_{in} = ((1 - \eta_{ind})\ /\ \eta_{ind}) * \sigma * B^2 * U^2_{in} * V_{ch} \tag{7}$$

The electrical power supplied to the MHD channel is,

$$P_e = V * I = ((1 - \eta_{ind})\ /\ \eta_{ind}) * \sigma * B * V * U_{in} * W * L \tag{8}$$

and the electrical efficiency is defined as, from Eqs. (7) and (8),

$$\eta_e = P_w / P_e = (B * U_{in} * D)\ /\ V \tag{9}$$

This is identical to the field induction efficiency, η_{ind}. This, however, does not mean one can extract the most mechanical power from the MHD channel at η_e (or η_{ind}) being equal to 1. As one can see from Eq. (8), P_e approaches to zero as η_e approaches to unity. From Eqs. (7) and (9), the expression for the mechanical power under fixed channel dimensions and electrical potential would be,

$$P_w = ((1 - \eta_e) * \eta_e * \sigma * V^2) * (V_{ch} / D^2) \tag{10}$$

P_w can be optimized by taking the derivative of Eq. (10) with respect to η_e and determining the value of η_e that satisfies a zero derivative. It turns out that P_w is optimized when η_e is equal to 0.5 (which is close to diesel and gasoline engines!). That also means 50% of the electrical power will be consumed as heat by

Ohmic loss, a condition that will always have to be taken into account in the thruster design (with respect to the in and out inlets geometry that will induce, also, some indirect loss in electrical efficiency).

We have also made some software simulations which confirmed the possibility of moving a small drone (experimental model) as seen in the graphic from Figure 4 (it was considered an electric conductivity of 5/(ohm*m)).

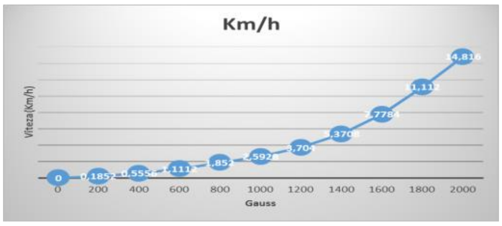

Figure 4 – Small drone speed / magnetic field (computer simulation)

Taking into account that the modern neodyum magnets can generate between 10 and 15 Kilogauss at temperatures upon 0 to 80 Celsius degrees, our simulation indicates a possible approximative speed of 2.5Km/hour (0,69 m/s) at 1000 Gauss.

Actually even in well developed countries such types of drones or other type of vessels using Magnetohydrodynamic Engines are poor documented. Despite that, some internet sources certify that such engines are already used, as secondary thrusters, on some stealth nuclear submarines or vessels in USA, Japan and Russia. In our country the Magnetohydrodynamic Engine (MHD Engine) is not yet covered as well as the related command and control methods, this being a real challenge for the Romanian researchers.

The high similarity of a MHD Engine with an electrical motor is also interesting because the principle of operation is reversible so that the motor can become a power generator. Also, the study of such an engine offers, in others future projects, new possibilities in the development of new sensors and actuators using the same principle. The experimental model can have all functional parameters transmissible to vessels with larger dimensions (invisibility, speed, movement accuracy, manoeuvrability, etc.). Our study predicts the possibility, for the first time in our country and probably in EU, to execute a complete functional and controllable marine drone able to execute stealth surveillance missions and/or interventions missions.

The results of such a project will open new an inedited research direction for Magnetohydrodynamic systems. The engine being unique requires without a doubt an intelligent command and control system. The movement of the drone must ensure both the proper positioning accuracy and, where appropriate, the simulation of the movements of an aquatic creature (in order to avoid and confuse extremely sensible dynamic sonars). For this, a complex wireless controller must be created, able to move the drone in the 4 important directions (forward, backward, left, right) and their normal combinations (diagonal movement back and forth and rotational motion to the left and right). In order to simulate a marine creature's movement only 3 base directions are required (forward, left, right) and their combined movements (forward diagonals and rotation to left and right). The backward movement and its combinations can be made optional but are required for faster rotations or in case the drone can't advance forward or can't rotate to change the direction. In the study is proposed that the drone is aiming a TRL 3 laboratory demonstrator level, but can also be designed to be easy upgraded to a more complex level (TRL4) able to operate in real marine conditions and easily reproduced in Romanian production industrial entities.

The purpose of the study has also taken into consideration the advantage of the vast experience of the specialists from our institute and from SC MDM Standard SRL, in the research, design, production, optimization and control of land and air drones, in order to create an undetectable marine drone based on a new, unique concept, regarding its motorization and it's effective control.

3. Conclusions

The conclusions were positive that an experimental model of a **marine undetectable drone** powered by a magnetohydrodynamic engine controlled by an artificial intelligence is feasible. The artificial intelligence also will demonstrate that drones having magnetohydrodynamic engines can be controlled in order to move coherently in the marine environment with high accuracies related to various surveillance and control missions. No compromises shall be made in order to maintain the un-detectability of the drone both in motion and stationery. The results of such research can be also extrapolated to real marine vessels having the possibility to assure the adequate energy needed to obtain the same parameters as the experimental model (speed, manoeuvrability, braking, etc.). The artificial intelligence must also be able to ensure total manoeuvrability of the drone, without any mobile guidance element.

So the general conclusion being positive, it is expected that the entities involved in this study will continue their fruitful collaboration by submitting a research project on the effective realization of such a drone.

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