PROTOTYPE OF THE UNMANNED MARINE SYSTEM "NEOGOBIUS-1"

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ABSTRACT

The paper presents the design of the unmanned marine system Neogobius-1 developed and built at the Polish Naval Academy. It is a surface remotely operated boat designed to carry out operational and reconnaissance tasks. The material also presents the results of preliminary functional tests of the system indicating that it has reached Level VII of technological preparedness. In 2021, the Neogobius-1 system won first place in the competition of the Ministry of Defence for the development and construction of an unmanned aerial/maritime system in the operational and reconnaissance category. Currently, the system is being used by students of the Naval Academy's Mechanical and Electrical Engineering Department to develop practical skills and solidify theoretical knowledge.
Keywords: sea engineering, mechanical engineering, automatic and robotics, unmanned sea vehicles.

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INTRODUCTION

Unmanned naval vessels are currently among the most vibrant trend in the development of technology used by man in the aquatic environment. The perspective of the last decade clearly shows that the division of naval forces according to specific, functional sets of forces of a combined capacity, equipped quite extensively with autonomous or remotely controlled technical devices will continue to gain importance. This implies that multi-modal surface and underwater surveillance systems will be used in the future for the defense of naval bases and ports and communication routes [1]. This approach has been recommended by the US Department of the Navy for nearly 20 years [2,3].

It should be noted that the commonly used term "drone" in the naming of unmanned ocean-technical objects is incorrect. A huge role is played here by the media, where the above term has made a spectacular career, used mainly as a synonym for modernity, and in relation to marine systems it stands in contrast to, firstly, tradition, and secondly, to the linguistic standard and current knowledge. When creating new technical terminology special rules apply to naming, one of which is the principle of unambiguity, which states that only one name is appropriate for a single concept [4]. In scientific writing, ambiguity should be avoided as technical concepts correspond to specific technical names [5]. A simple conclusion from this is that an aircraft and a marine vessel should not be referred to using the same name. The name drone has been assigned in technical terminology to an unmanned aerial vehicle [6,7]. Traditionally, unmanned naval vessels, whose design and operating principle originated in shipbuilding, are referred to precisely as vessels or vehicles, as a result of the translation of their English acronyms and naval origins. Moreover, looking at it from the ground of the floating objects theory, the name drone combining an aerial vehicle with a floating vessel is ambiguous and misleading, since an aerial vehicle does not have a center of buoyancy, and thus it lacks a metacenter. An attempt to overcome this situation by using the auxiliary term "underwater drone" or "surface drone" is considered to be breakneck, as it would mean either an unmanned vehicle flying underwater or an unmanned vehicle flying on water. For the above reasons, calling the broadly defined family of unmanned marine vessels by the term "drone" constitutes a gross methodological error.

Taking into account the above-mentioned recommendation of the US Navy Department, as well as our own observations and the development needs of the Polish fleet, various types of research work have been carried out at the Naval Academy for a number of years on the construction of unmanned marine vessels, for example, such as an unmanned autonomous surface boat called "Edredon" [8]. One of the most recent manifestations of this activity is the construction of a prototype of a multipurpose unmanned surface boat with very specific properties and functions of purpose, which can find various applications, from military applications to research and development, which only confirms the thesis that it is a dual-purpose technique. By design, the vehicle, with the working name Neogobius[1], is a double-hulled floating platform with a distinctive interchangeable mast for installing various types of sensors and a ballast keel. The vessel was built at the Department of Mechanical and Electrical Engineering of the Naval Academy in Gdynia.

THE CONSTRUCTION OF THE NEOGOBIUS-1 SYSTEM

The unmanned marine system Neogobius-1 consists of three essential components (Fig. 1):

- a surface boat, the supporting structure of which consists of two independent sealed hulls made of reinforced laminate,
- a management subsystem - a workstation for remote management of the boat's operation during operation containing a control and video observation module,
- transport and storage equipment.

The hulls of the vessel, with a total length between the uprights of 1528 mm, were made of polyester-glass laminate with a thickness of up to 7.5 [mm] with a laminated screen mesh to minimize physical fields. Free spaces were filled with closed-pore polyurethane foam to increase the craft's unsinkability. The hulls are separated from each other and tightly sealed to counteract possible flooding of equipment housed inside (Fig. 2). The width of the two hulls connected by a mounting rack is 833 mm. The total load displacement is 95 kg. On board the vessel there is an on-board computer with software, a GSM GPS receiver, remote control apparatus and four cameras - two FPV type controlled cameras, one high-speed camera and an auxiliary camera with analog and digital transmission systems. All electronic components were built in sealed separate containers with forced cooling.

Fig. 1 Unmanned marine system Neogobius.

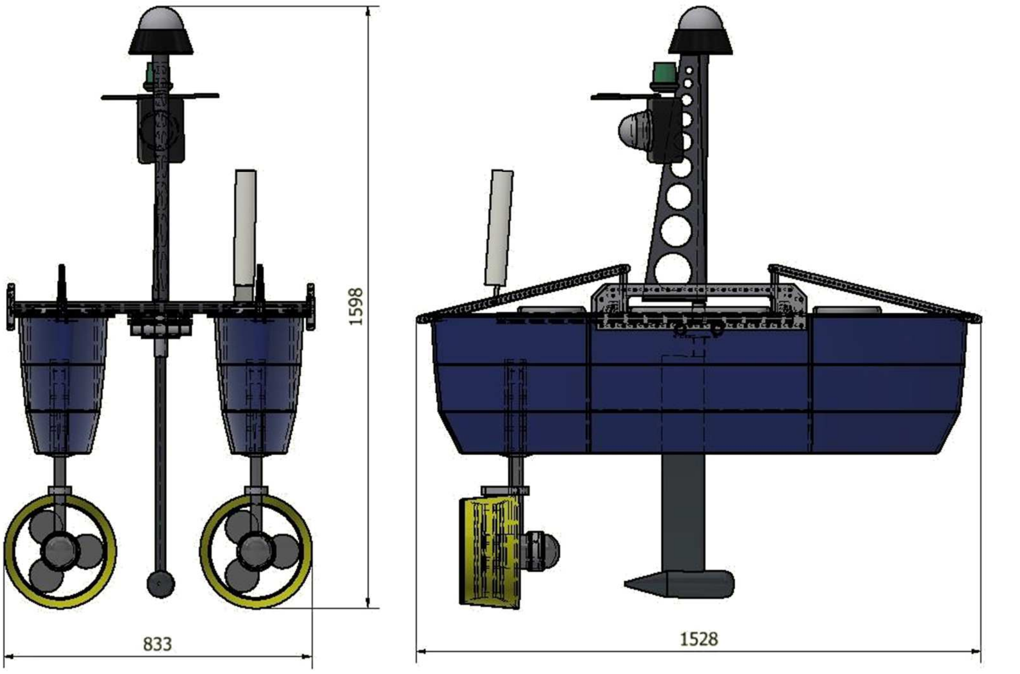

Fig. 2 Main dimensions of the Neogobius system.

The vessel is equipped with a navigation lamp, an independent GPS locator, a tiphon, an emergency stop switch, safety features and fail-safe mode software - which is programmed to activate in case of loss of communication with the remote command and control station. The propulsion system of the vessel consists of two DC brushless motors mechanically coupled to a three-blade screw propeller with a diameter of 240 mm located in rotating Kort nozzles. Four lithium-iron-phosphate batteries are fitted on board the vessel with built-in protection system against the effects of uneven charging, overcharging, over-discharge or overheating, coupled with a block of super capacitors to support dynamic power states. Two batteries are designed to power the vessel's electronics, and two are designed to power the propulsion system.

The remote monitoring and control station consists of three major components housed in two portable trays. The largest component of the station is a tray equipped with a communication system with the vessel's video system (digital and analog). It implements a rotating camera control system and a recorder for collecting and post-processing video data from digital cameras. The built-in power source allows up to 15 hours of operation for all connected components of the workstation. It is equipped with an installation that allows wireless use of Internet network resources within the station. The second tray is equipped with an apparatus that enables manual control of the unmanned marine vessel. It includes a system for viewing the vision from FPV cameras used to conduct navigation. The built-in rechargeable battery allows operation in case the first tray is not connected. The third independent component is a computer used for mission planning. It is equipped with a telemetry module, which makes it possible to send tasks to the unmanned marine vessel's on-board computer (up to 15 km) and receive parameters regarding the vessel's status, such as geographic location, speed, power source parameters, heeling. The design of the remote control station allows a two-person staff to prepare it for operation inside two minutes. The station can operate independently powered from built-in batteries, or it can be powered from the power grid.

A specially designed transporter, shown in Figure 3, has been developed for transporting, launching and storing the system. The transporter allows a number of variants of launching and retrieving the boat from the water. With its help, the boat can be slipped (rolled down a ramp), a davit can be used to lower or raise the boat from the deck of a vessel or quay. Lastly, it can be moved into the water manually, which requires four operating personnel. The total weight of the Neogobius system including all components is 150 kg.

PRELIMINARY FUNCTIONAL TESTING OF THE SYSTEM

Tests of the system in question were planned in conditions approximating real ones, in the harbour basin and in the roadstead of the port of Gdynia. Prior to the implementation of the tests in sea waters, the first check was performed on an inland body of water (Fig. 4). The purpose of the tests was to check the structural design and verify the interoperability of system components, as well as to determine some operational parameters.

Fig. 3 The Neogobius system in the transport variant.

Fig. 4 The Neogobius system during preliminary functional tests in an inland body of water.

Tests in an aquatic environment showed that the thrust of the two-screw propulsion system is a total of 55 kg. In addition, it was found that the assumption of locating the screw propellers quite deep works well during wave floating. The propellers do not suck in air during dynamic maneuvering and in waves, and the rotating Kort nozzles provide considerable maneuverability of the vessel. In addition, the vessel was found to have a substantial power reserve to tow objects many times heavier than it. The maximum horizontal speed was 4 kn. The energy reserve stored in the batteries on the boat allows it to sail at a speed of approximately 3 kn within up to 4 hours, and at speeds of up to 2 kn within up to 10 hours. Meanwhile, the batteries powering the remote command and control station allow for 15 hours of independent operation of the station. In addition, it was found that a stabilization system for the observation camera is required, either programmed or mechanical. It was also noted that the structure should be equipped with an audible anti-collision system to signal the approach of an obstacle, or a stereoscopic camera system should be mounted for the operator, who could then independently determine the distance from obstructions.

Preliminary functional tests of the Neogobius system have demonstrated the correct interaction of the system's mechanisms and components, and allowed the definition of key performance parameters. They also indicated potential directions for the development of the device, such as in the area of observation cameras and the anti-collision system. The research also showed that it is inexpedient to continue pursuing the miniaturization of the device's design, as this would limit its marine prowess.

CONCLUSION

The material describes the engineering of the unmanned marine system Neogobius and presents the results of preliminary functional tests on this device. The results of the tests confirmed that the developed structure works well in operational conditions in coastal and inland waters, thus a demonstration of the technology prototype has been carried out, and accordingly Level VII of technology readiness development has been achieved. Naturally, the solution can be further developed. The design was not developed as part of any research project, it was an activity within the AIROMECH scientific circle operating at the Electrical Propulsion Laboratory in the Department of Ship Electrical Engineering and in cooperation with the Department of Underwater Works Technology. Currently, the device is used by students of the Faculty of Mechanical and Electrical Engineering at the Naval Academy in Gdynia and provides a basis for the development of practical skills and consolidation of theoretical knowledge. It can also serve as a starting point for further work on the development of this type of solutions. The developed and improved design concept can find a wide range of applications in maritime activities from military operations to scientific research.

In the middle of 2021, the Neogobius vehicle was submitted to the competition of the Ministry of Defense entitled "*Development and implementation of an unmanned aerial/maritime system design*," where it won first place in the operational and reconnaissance category.

Fig. 5 The team developing the design of the Neogobius vehicle: on the left Karol Szumacher (currently a student is in his fourth year of mechatronics), on the right Capt. Seaman Przemysław Chrabąszcz, M.Sc.

[1] Neogobius caspius – a genus of perch-like fish from the goby family.

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