The study of the process of the development of marine robotics

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(Received 25 June 2016; accepted 27 June 2016)

Abstract. Most projects of similar research are applied and become known mainly due to their commercial implementation. Undoubtedly, in the modern realities, it is more and more difficult to conduct scientific research regardless of the urgent production problems. Thus, cooperation of commercial structures, research institutions, military departments, etc. is required for the successful implementation of most projects. Certainly, the results of such projects can be effectively used by all the organizations listed above. For example, almost any innovation in the surveillance and search, under-ice and other studies in one form or another can be used for strategic or tactical military purposes.

Keywords: experimental autonomous, oceanographic research, autonomous underwater vehicles.

1. Introduction

In the scientific surroundings, the statements that Oceanographic researches are, in many aspects, more complex and challenging, even compared to space research are not rare [1]. Now, in the middle of the second decade of the XXI century, there is no doubt that the study of the oceans has become an issue of global importance, covering economic, industrial, social, defense and many other activities and interests of the society in the modern world. We are seeing the necessity of expanding the boundaries of Oceanographic research, increasing the number of types and growth of quality of measurements in the water column as well as their systematization, increasing of the depths of research, which is caused by the growing necessity of sea bottom studies, etc.

2. Historical development. Autonomous underwater vehicles

In the present, article the author gives an overview of the historical development of underwater technical vehicles and dwell on the modern representatives of this class of vehicles – Autonomous (Unmanned) Underwater Vehicles (AUV). The authors touch upon the structure of this class of vehicles, problems to be decided, and perspective directions of their development, cover scientific materials basing mainly on the data about the benefits of the application of the vehicles in a number of tasks of narrow focus.

The development of the AUV was largely aimed at the decision of the review-search problems: exploration of the sea-bottom by means of echolocation, photos and video shootings, search for underwater objects, making of different measurements. Subsequently, thanks to the progress in the development of the AUV, these tasks have expanded from search to exploration and analysis. Currently, there is a rapid development in the use of AUV for geological exploration, monitoring and examination of places of gas and oil production, search and control of the state of different objects of underwater communications, including oil and gas pipelines and various underwater cable routes. In some countries, one of the priority directions of the use of the AUV is ecological research.

But, historically, combat torpedoes can be considered the first samples of AUV [10].

The first man to express the idea of a self-propelled sea shell was an Italian engineer Giovanni da Fontana [2] who lived in the early fifteenth century. For the first time the term “torpedo” as a sea munition was used by Robert Fulton in the early nineteenth century. In the nineteenth century, many engineers developed different projects of underwater self-propelled shells. In 1865, the Russian Inventor I. F. Alexandrovsky proposed "a self-propelled torpedo".

The first samples of torpedoes (Whitehead torpedoes) were developed by the Englishman Robert Whitehead (1866). On the 29th of May 1877, during the battle in the Packocha Bay, the torpedo was first used by the British Navy as weapon, but to no avail – the goal managed to evade being hit.

In Russia, for the first time, torpedoes were successfully applied during the Russo-Turkish war of 1877-1878. On January 14, 1878, during the sea battle of the Russian Navy conducted under the leadership of Admiral Makarov against the Turkish Navy in the district of Batum, two boats, "Chesma" and "Sinop", released from the destroyer "Grand Duke Constantine", sank the Turkish steamer "Intibah". Torpedoes were also actively used during the first Russo-Japanese war.

By the way, during the First World war, torpedoes were used by the warring sides not only at sea but also on rivers, for example, on the Danube.

These devices evolved in each generation and modification, subsequently becoming the prototype of a number of AUV of civilian use. Their engines originally used compressed air (before the First World war), then they developed into steam and gas devices with the turbine or piston engine, where liquid fuel is combusted in oxygen and water. After that, there were attempts to use powder engines where gases of burning gunpowder rotates the shaft of the engine or turbine. Then, constructors came to the idea of using electric propeller engines, battery-operated – this construction is most widely used both in military and in the civilian sphere.

Jet engines have become another type of AUV. They do not have rowing screws and use jet thrust (torpedo "Squall"), which allow to obtain the velocity of the torpedo of over 200 nodes. However, each engine has its advantages and disadvantages. Thus, the necessity for innovation in this area is still relevant.

In addition to the type of engine and propulsion engine, active search for new engineering solutions were in the field of guidance of torpedoes at the target. The first torpedoes were unguided. Further, by way of guidance there appeared the following modifications: straight moving, maneuvering, passive homing, active homing, and remote-controlled.

Straight moving torpedoes moved along a predetermined straight path, staying on course thanks to a magnetic compass or gyroscopic sub-compass. Maneuvering torpedoes moved in the area of the suspected target according to a given program. Passive homing torpedoes, as a rule, were aimed at a target by the noise or change of the water properties in a Wake trail (the first torpedoes were acoustic torpedoes G7e "Zaunkönig" (German, "The Wren"); they were applied by German submarines in World War II).

It is known that two submarines of Germany, T5-U-972 in December 1943 and U-377 in January 1944, (a similar case is known about the American submarine "SSN-589") were destroyed by their own torpedoes. The fact is that after the launch the acoustic system of a torpedo was aimed at the most intense sound source that could be heard at a distance of the first 400 meters, and this source could be the submarine itself. Thus, after making the shot, according to the instructions, the submarine immediately had to dive to a depth of 60 meters, keeping complete silence.

Torpedoes with active homing guidance systems (Fig. 1) use on-Board sonar. Many modern anti-submarine and multi-purpose torpedoes are equipped with such systems. At the same time, there was an active development of the first homing systems, that could use yaw, or right and left circulation to follow the course and locate the target.

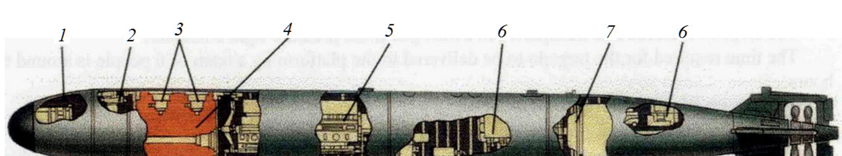

Fig. 1. Homing electric torpedo [3]: 1 – guidance system; 2 – proximity fuse; 3 – contact fuses; 4 – warhead; 5 – accumulator battery; 6 – control devices; 7 – electric engine

There are also remote-controlled torpedoes (Fig. 2), in which the targeting is done by wire (fiber) coming from the ship or submarine.

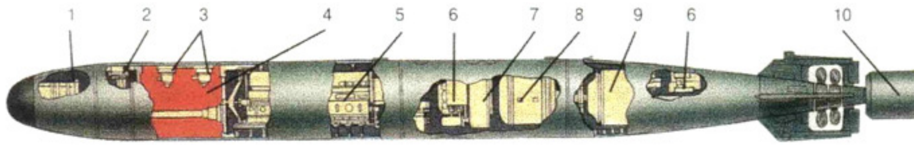

Fig. 2. Layout scheme of a torpedo [3]: 1 – guidance system; 2 – proximity fuse, acoustic and electromagnetic; 3 – contact fuses; practical torpedo – recording device); 4 – charger fighting compartment (on a practical torpedo – a means of providing buoyancy); 5 – disposable batteries (on a practical torpedo – reusable); 6 – course management system; 7 – the electronic unit; 8 – telecontrol system torpedo coil; 9 – electric engine; 10 – towable coil remote control system

There was also the evolution of warheads and the systems that reduce noise. Warheads can be divided into those that use contact or non-contact fuses. Contactless systems are of great interest: various kinds of sensors to detect the target were developed for them. They usually were induction sensors that responded to the change of the vertical component of the magnetic field observed at the approach to the housing target.

In general, the main objectives of the development of the first AUV for combat purposes were distance, speed, quietness, the ability of homing at unsighted shooting, detection and target recognition in the approach thereto, the adaptive system that separates the useful signal against the background noise, etc. It is obvious that all the results achieved when solving the problems, were subsequently of great use in developing research types of AUV. In fact, the very structure of most of the AUV has remained almost unchanged and has retained the layout inherent in the torpedoes (Fig. 3), with the only exception that instead of warhead they carry scientific research equipment.

Fig. 3. Structure of AUV “Gavia” [4]

The main results of the development of AUV in the second half of the twentieth century.

We can say that until 1970 there were the initial surveys in the questions of what problems can be solved with the help of AUV. AUV development began in the 1960’s, and although a few models were built, there is no any detailed publication about their success left. The development of the first AUV was aimed at solving a very narrow task, mainly collecting data. After the Second World War in technical terms, the main development followed the way of copying and attempts improve the captured samples technology, developed in Germany. The initial significant development of the technologies of AUV and study of their potential occurred from about 1970 to 1980. At the applied physics laboratory of the University of Washington made such apparatuses as SPURV (Special Purpose Underwater Research Vehicle) and UARS (Unmanned Arctic Research Vehicle), the drafting of which began in 1957. UARS was one of the first AUV, which performed part of the work in under-ice space. In 1979 the apparatus SPURV II was taken on the balance of the United States Navy. It was an improved version of the first model: its autonomy speed and diving depth were increased.

Since 1960’s the engineering laboratory of marine systems the University of New Hampshire (present-day Institute of the Autonomous undersea systems) under the auspices of the Pentagon had been developing a series of machines EAVE (Experimental Autonomous), which were created as cheap remote-controlled underwater devices. The main purpose of these machines was the inspection of subsea pipelines. The first model EAVE Free Swimmer II had mission planner, an acoustic navigation system, and fiber optic cable for communication with the operator. It came back and found the place of docking itself.

It should be noted that even at that time there were rather successful attempts to create devices capable of planning the route, implementing visual navigation along pipe line with automatic system of maneuvering and location control.

Fig. 4. AUV SPURV (USA)

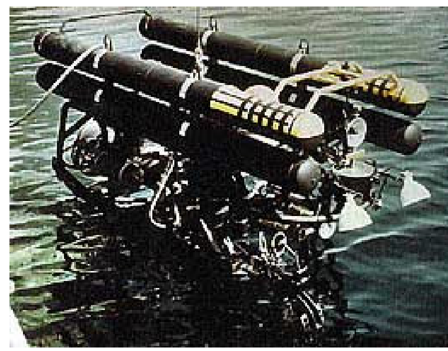

Fig. 5. Cable-controlled undersea recovery vehicle CURV

In 1979, the French AUV "Epaulard" performed geological studies of one of the districts of the Pacific Ocean to explore the deposits of ferromanganese nodules. This was the first application of AUV for such purposes.

In the 1970-1980s, there was the development of the project of CURV (Cable-controlled Undersea Recovery Vehicle). The first prototype of CURV appeared in the early 60-ies. It was a remote-controlled underwater device with a camera; the device was used for search and inspection of sunken bombs and shells at depths up to 1000 meters. In 1973, thanks to model CURV III it appeared to be possible to locate and rescue the crew of the sunken off the coast of Ireland the submarine Pisces III.

The devices of this series had a small length of about one meter and were the basis for the subsequent creation of the RUWS (Remote Unmanned Work). The devices of this class operated at depths up to 6 kilometers, and the manipulator arm with seven degrees of freedom could take into account the compression force of the control by the human operator. Camera CURV III (Fig. 5) is used up to this day.

In our country, the active development of similar AUV can also be attributed to the early 1970s of the last century. NGOs "Yuzhmorgeologiya" located in Gelendzhik, Feb RAS and the NGO Dalmorgeologia" in Nakhodka took part in this work. From 1974 to 1992 the country has developed such types of AUV as "SKAT", SKAT-geo (Fig. 6), "L-1", "L-2", "MT-88", "Tiflonus", "MT-GEO", "R-1" and "R-2". Then, it was followed with a number of international projects.

"Scat" was the first AUV of its kind, developed in the USSR. It made it possible to conduct research at depths of up to 300 m. The first development of the domestic AUV allowed to get experience that became the basis for subsequent developments, which included the first AUV for deep-water studies like "L-1" (working depth up to 2000 meters) and "L-2" (working depth up to 6000 meters). It should be noted that working depth of diving up to 6000 meters is sufficient to reach the 98 % of the bottom of the world ocean of the Earth. These devices were the first modular AUV that allowed people to work at such significant depths.

In 1982, AUV "L-2" (Fig. 7) performed inspection work in the area of the death of the nuclear submarine “K-8”, which was at a depth of about 5,000 meters. During that work, more than 80 dives were made and tens of thousands of panoramic images of the surveyed area were taken.

In five years, with the same apparatus, search and inspection were carried out in the place of crash of the submarine “K-219” near the Bermuda Islands. Then, using the “L-2” rescuers managed to not only find the scene of the accident but collect more than forty thousand photographs. And then, in two years, the apparatus participated in the examination of the sunken submarine Komsomolets in the Norwegian sea.

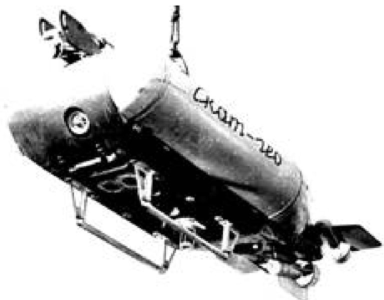

Fig. 6. AUV “SKAT-geo” [4]

Fig. 7. AUV “L-2”. Work in North Atlantic, in the area of the death of NSM “K-8” 1982 [4]

3. Conclusions

The implementation of such projects requires solving a set of problems, as AUV projected in their framework has to inspect objects with a length of hundreds of kilometers [6-9]. Accordingly, the inspection devices need to solve problems of gathering information from a variety of vision systems, processing of this information, object recognition, intelligent control. As a rule, they are required to examine not only the condition of the pipeline, but also to collect data of environmental studies in place of its location. With the increasing relevance of the task of inspection of means of underwater communication, the demand for corresponding AUV grows too, as there are no alternatives to these devices.

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