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Analysis on the development of Autonomous Underwater Vehicle Equipment in the Deep Sea

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Abstract

As an undeveloped field, deep-sea resources have become the focus of research all over the world. Deep sea environmental survey is an important work for the development of deep sea resources, but the deep sea environment is bad and there are various unknown conditions. The deep-sea autonomous underwater vehicle has unique advantages in reducing platform costs, reducing casualties, and operating in harsh environment which has become an important tool for deep-sea environmental investigation. In this paper, the development status and key technology level of deep-sea autonomous underwater vehicle equipment are studied, the future development trend is predicted, and provides reference for relevant researchers.

Keywords

Deep sea resources, deep sea exploration, autonomous underwater vehicle(AUV).

1. Introduction

There are a lot of resources stored in the deep sea, including combustible ice, submarine oil and gas, various metals and cobalt-rich crusts; they are important alternative resources for future terrestrial mineral resources. However, due to the constraints of the harsh environment in the deep sea, human development and utilization of deep-sea resources is still very limited. At present, countries are competing to join the "deep sea competition" to accelerate the pace of occupation of deep-sea resources. At the National Science and Technology Innovation Conference, the country clearly put forward the deep-sea "trilogy" strategy of "deep sea entry", "deep sea exploration" and "deep sea development". Among them, "deep sea exploration" is an important part of China's deep sea, and deep-sea unmanned submersibles are an important tool to undertake this task. Deep-sea unmanned submersibles have low cost and strong environmental adaptability, and have become one of the major equipment for deep sea exploration in various countries. In recent years, countries have made certain breakthroughs in the development of equipment technology for deep-sea unmanned submersibles, and have been used to perform tasks such as deep-sea marine environmental surveys and resource exploration.

2. Development Status

Constrained by unmanned submersible structure and energy, the deep-sea unmanned submersibles studied in this paper mainly refer to unmanned submersibles with a more than 1000 meters depth and can operate deep-sea environment operation, and are classified into two categories according to their navigation modes. One type is a water glider driven by buoyancy; the other is a heavy and giant unmanned submersible that relies on electric energy to sail, and is divided into portable according to the weight, displacement, load and endurance of the autonomous underwater vehicle, it can be divided into portable, light, heavy and giant. The water glider can convert gravity and buoyancy potential

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energy into kinetic energy. It is a new technology platform for large-scale marine environment observation. The concept design of the water glider began in the 1950s. By the mid-1990s, the United States, with the support of the Naval Research Bureau, had developed a number of operational water gliders, including the electric-driven water glider from Weber. The Institute of Oceanography's "jet" water glider, and the University of Washington's series of water gliders. At present, the United States, France, Japan, Italy, Canada and Singapore have carried out research work related to water gliders, but most of them are in the development stage except for the production of products from the United States and France.

In order to protect the deep-sea pressure resistance and hydrodynamic characteristics, the shape is mostly torpedo-shaped, and in order to meet the endurance requirements and sensor power consumption, the energy mainly uses high-performance lithium batteries and fuel cells. A few models use alkaline batteries. At present, the United States deep sea operations unmanned submersible technology level is high, sensor technology is advanced, in addition to use for marine surveys can also perform intelligence surveillance and reconnaissance tasks. Russia started earlier and developed slowly. However, in order to control the resources of the Arctic Ocean, we are now attaching great importance to and actively developing deep-sea unmanned submersibles. Other European countries are also equipped with deep-sea unmanned submersibles with excellent performance, mainly for deep sea environment detection and research. The development level of Japanese and Korean unmanned submersibles is generally backward, but there are also models that can perform tasks below 3000 m. Among them, Japan’s “Pudao” is one of the deep-sea operation unmanned submersibles using advanced fuel cell technology.

3. Typical Equipment

3.1 US "Slocum" water glider

The "Slocum" water glider was developed in 1992 by the American company Teledyne Weber to complete the water gliding test in 1998. Considering its outstanding military potential, the US Navy has further developed the military version of the "Slocum" water glider "Offshore Battlefield Sensing Glider". In 2016, China has salvaged this type of water glider in the South China Sea. Fig.1 is a schematic diagram of the action of the "Slocum" water glider and measurement mode.

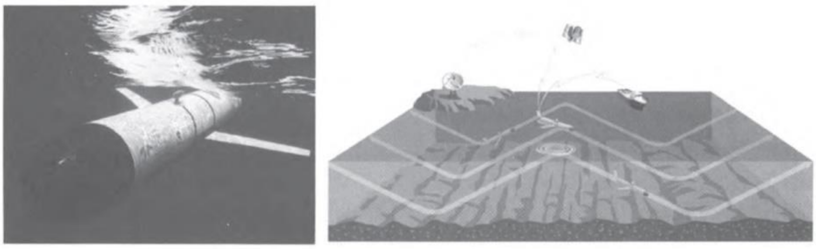

Fig.1 Slocum water glider and measurement mode action diagram

The Slocum series gliders are divided into two types: electric power driven and temperature difference driven. The electric power driven type regulates volume through water injection and drainage by water pump, rotation control by rudder surface and pitch control by moving mass block. However, the working water depth is limited by the strength weight ratio of the body material and the pump regulating the volume, only 1000 m; the temperature difference driven type can last longer and navigate farther in the ocean with obvious thermocline, and the working water depth is more than 2000 m.

The maximum speed of Slocum series gliders is about 0.68h, the electric power driven endurance is 30 days, and the thermal energy driven endurance is up to 5 years. The glider can be equipped with a modular design of acoustic, optical, chemical and other professional sensor package. Its main characteristics are low cost, low power consumption and strong endurance. It can be used in many fields such as marine environment monitoring, underwater moving target tracking and monitoring, underwater intelligence collection and key sea area data acquisition. At present, the autonomous

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underwater vehicle is widely used in many areas, such as under ice, open sea and offshore, and is purchased by the National Science Foundation of the United States for the integrated ocean observation system.

3.2 Seaglider autonomous underwater vehicle

The Seaglider autonomous underwater vehicle was developed by Washington University in 1999, and the Deepglider autonomous underwater vehicle was further developed by improving the material dynamics model and strength of Seaglider in 2002. The main difference between the two types of gliders is that the shell of Deepglider autonomous underwater vehicle is made of thermosetting resin and carbon fiber, with a submergence depth of 6000 m, while the shell material of Seaglier adopts aluminum structure, the submergence depth is about 1000m. Fig.2 shows the Deepglider.

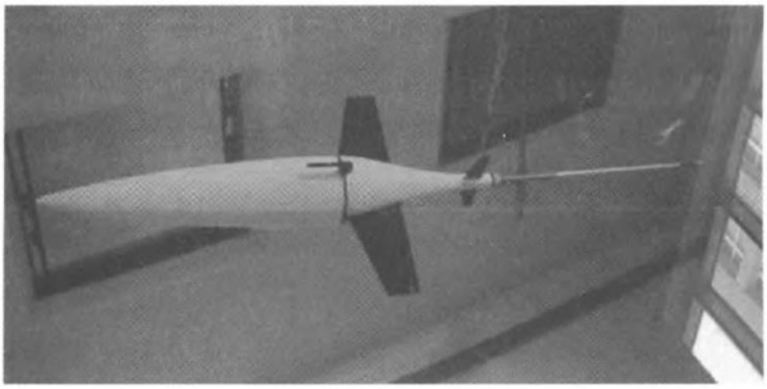

Fig.2 Deepglider

At present, Deepglider and Seaglider are mainly used for deep-sea exploration. In 2011, the test team of University of Washington launched three Deepglider Gliders in the Atlantic Ocean for sea trial research, with the maximum diving depth reaching 5920 m and a total range of 275 km; in 2015, the test team of University of Washington again launched Deepglider Gliders in the western waters of the Atlantic Ocean to further test the data collection and transmission of the glider platform, which has been tested in 2017, the underwater research task lasted for 18 months.

3.3 Energy technology

The general principle of the underwater glider design is to change the volume of the glider, thus changing the buoyancy of the glider. The vertical motion formed by the lift provided by the wing and contour is converted into horizontal motion. The electric drive type relies on the alkaline battery or lithium battery to provide energy. It uses water pump to pump seawater or change the volume of the external air bag, so as to change the density of the glider. However, the volume change of the underwater glider driven by the temperature difference energy is related to the melting and solidification of the internal paraffin, and the endurance range can reach 3-4 times of that of the conventional electric glider.

For the deep-sea heavy-duty and giant unmanned underwater vehicle, due to the special working environment and the size limitation of deep-sea unmanned underwater vehicle, its energy can meet the use conditions of high specific energy, good safety, low temperature resistance, high pressure resistance, etc. At present, the secondary lithium-ion battery is one of the commonly used batteries for deep-sea unmanned underwater vehicle. Its specific energy can reach 210 WH / kg, which is twice as long as the silver zinc battery (alkaline battery), and its service life is 130 times. Due to its advantages of low temperature, high efficiency and low consumption, fuel cell is suitable for deep sea heavy and giant unmanned underwater vehicle. Seahorse in the United States can be powered by full fuel cells with a endurance of up to 125h; the "Xiujin" series can be powered by A1/H2O2 semi fuel cells, which are easy to fill and maintain. In addition, developed countries are also developing new power source radioisotope batteries (i.e. nuclear batteries). This kind of battery has the

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advantages of light weight, long life, no need to repair or supplement, etc. it can make the underwater vehicle navigate for a long time and is a very ideal energy source.

3.4 Independent control technology

The working environment of the deep sea is very complex, and the UAV needs to have the ability of feeling, cognition, analysis, planning, decision-making and action. Its autonomy will become a power multiplier, which can not only make it adapt to the harsh environment, but also improve its ability to carry out deep-sea missions. Autonomous Control of UAV involves many aspects, including algorithm, architecture, etc., which determines how to process the acquired data, how to simulate the process of thinking and action. At present, foreign deep-sea unmanned submersibles, such as "hujin-3000" and "remus6000", can make a certain degree of independent judgment on the predetermined path, such as obstacle avoidance, detour, path optimization, etc., and can also use underwater acoustic communication to intervene in the unmanned submersibles in case of emergency. The future development direction of autonomous control technology is to further optimize the logic algorithm, path optimization method, and develop the collaborative ability to improve the level of autonomous control.

3.5 Navigation technology

The main navigation systems used in the UAV are inertial navigation system, Doppler velocity log, gyrocompass, GPS positioning system and underwater acoustic navigation system. At present, the inertial navigation system, together with the Doppler sonar log and GPS positioning system, is the mainstream navigation system, while the underwater acoustic navigation system, gyrocompass and other auxiliary navigation equipment are mainly used. The integrated navigation accuracy of the standard configuration is 0.1% of the range, and that of the low-cost configuration is 1% of the range. Due to the long-term use of deep-sea autonomous underwater vehicle in the deep sea, the inertial navigation system may accumulate large errors. The underwater acoustic navigation is limited by the applicable areas and the impact of the marine environment, while the terrain navigation, geomagnetic navigation, gravity field navigation and other technologies are not mature. Therefore, the precise navigation and positioning of the UAV in the deep sea for a long time is still a technical difficulty at present.

3.6 Communication technology

The classic communication forms adopted by the UAV mainly include radio communication, satellite communication, network communication, optical cable communication, Ethernet communication and underwater acoustic communication. Underwater acoustic communication is mainly used in deep-sea autonomous underwater vehicle. Advanced underwater acoustic communication system such as uwm4010 acoustic modem has working frequency of 12.75khz or 21.25khz, working depth of 3000m or 6000m, transmitting power of 7W, receiving power of 8W, transmission distance of 4km, load data rate of 3.2kb/s and bit error rate of 10 ~. However, underwater acoustic communication in the deep sea has many problems, such as large energy consumption, large background noise and limited transmission distance. Other communication methods can be used for deep sea autonomous underwater vehicle in shallow water. The data volume of radio communication is large, more than 10 KB / s, and the communication distance is several kilometers or even dozens of kilometers. Satellite communication mainly relies on low orbit Iridium satellite communication, which is mainly used for large amount of information short-term communication between the UAV and the shore command center and the UAV, with the maximum data amount of 115.2kb/s. Optical fiber communication can be used for the short-term and large data cable communication between the UAV, with a communication rate of up to 30 GB / S; however, it has poor mobility and is easy to be affected by the temperature difference. Ethernet communication is usually used on board or on shore, and the data volume can reach 100 GB/s. In addition, as the future development hotspot, the blue-green laser communication mainly needs to solve its shortcomings of large volume, energy consumption and low efficiency.

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4. Conclusion

The world's deep-sea autonomous underwater vehicle equipment is booming, technologies continuously innovate, and application scenarios are more extensive. The endurance of deep sea autonomous underwater vehicle will be greatly improved, and it will develop towards the direction of independence and coordination. China should seize "deep sea entry" development opportunity, and speed up the development of "deep sea exploration", so as to grasp the initiative of "deep sea development" in the fierce competition.

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