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Analysis of New Developments and Key Technologies of Autonomous Underwater Vehicle in Marine Survey

Minqiang Tang [a,b,c,d]*, Zhiqiang Zhang [b,c,] Yuqing Xing [b,c]

[a]*Key Laboratory of Marginal Sea Geology, South China Sea Institute of Oceanology, Chinese Academy of Sicences,Guangzhou, 510301,China*

[b]*key Laboratory of Technology and Application for Safeguarding of Marine Rights and Interests, SOA, Guangzhou, 510300, China*

[c]*South China Sea Marine Engineering surveying Center, SOA, Guangzhou, 510300, China*

[d]*Graduate University, Chinese Academy of Sciences, Beijing, 100049, China*

chunxiao_tang@21cn.com

Abstract

The paper illustrates some marine survey AUVs plus their features and typical configurations, and analyzes their key technologies through classification and analysis, which are currently existed or under development. Their composition can be divided into basic modules and functional modules. Basic modules include central processing system, propeller system, power supply system and navigation system etc. Meanwhile, functional modules refer to auxiliary sensor and survey equipment. As for AUV applied in marine survey, designer should pay more consideration to the running state in high velocity flow and strengthen the control of side thrust. The configurations of marine survey AUVs from companies like Kongsberg in Norway, Hydroid in U.S., Bluefin Robotics in U.S. and Hafmynd in Iceland are analyzed and classified. The research and development process of domestic AUV are also be reviewed. As AUV can collect data with highly efficiency and better quality, it will replace traditional means of surface vessels with towed systems for its portability. Easy use of AUV can significantly reduce fuel consumption of ships, which will be widely used in marine survey in the future as a cost-effective method.

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Keywords: Marine survey, AUV, new development, key technologies analysis.

1. Introduction

21st century belongs to the era of ocean. Numerous mineral resources, biographic resources and energy in the ocean are considered as great treasure in sustainable development of human society. Ocean exploration has become the strategic focus of many developed countries. Among various ocean

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technologies, underwater vehicles lead ocean exploration to a new era as an economic, reasonable, and effective method for marine survey. Based on key technologies of AUV analyzed in this paper, we list some AUVs of marine survey products around the world plus their features and typical configurations. Meanwhile, the history of research and development of domestic AUV will be also reviewed here.

2. Introduction about AUV

Current common underwater vehicles mainly include ROV (Remote Operating Vehicle) and AUV (Autonomous Underwater Vehicle).

Traditional ROV carries electrical power and transfers data along a group of cables. The use of deck control unit carry out manual operation of underwater and some fine motions. ROV needs to be equipped with A-frame bearing, winch and other equipment, by which the working area of robot and its efficiency are greatly restricted.

As a new generation of underwater robot, AUV possesses a self-contained power supply and control system without any external cables or data transmission. It can navigate intelligently and automatically underwater through pre-set program. Because of its great commercial significance and large technological challenges, AUV attracts more and more attentions from sciences and technicians. Since 1970s, countries around the world began to research and develop AUV for various uses. Typical military missions for AUVs are demining, detection and coordinated operations for aggression etc. While AUVs can also be deployed in coast and offshore inspection and repair, cabling and other marine environmental surveys for commercial functions [1].

As the international AUV manufacturing technologies develop, particularly progress and popularity of integrated automation control system, inertial navigation technology and underwater positioning technology, the cost of AUVs gradually reduces to a sustainable level. Even some parts of AUVs at measurement level have emerged to be produced massively.

3. Analysis on key technologies of AUV in marine survey

Oceanographic survey AUV is equivalent to an abbreviated version of the military one. Military AUV requires strong and accurate target identification and capabilities to attack. But marine survey AUV only needs reasonable navigation and collision avoidance functions. Then it can be configured with sensors and other equipment corresponding to relative marine surveys. The composition of marine survey AUV can be divided into basic modules and functional modules as the figure 1 describes as follows.

Generally speaking, the basic modules cover power supply system, automatic control system and navigation positioning system. Automatic control system includes propeller system of AUV and central processing system, which take responsibilities of receiving all the data from sensors and decide to control AUV motion, then gather and record data depending on conditions. Navigation positioning system is determined by systematic accuracy requirements and specific requirements of the type of oceanographic survey. The simplest system is DGPS used on the water surface, then underwater inertial navigation system INS and underwater positioning ultra short baseline system USBL. Some small AUVs in the shallow water only need to use DGPS, on which the GPS antenna can stretch out of the water through short butts to receive satellite positioning data via investigation. Sometimes both water surface DGPS plus inertial navigation technology are made use of. AUVs spend most of time searching underwater by means of INS navigation. After some time and distances interval, AUVs will climb up on top of the water, making use of DGPS to correct the data from INS and dive automatically for continuous investigation. With higher accuracy requirements, inertial navigation technology and USBL can be used simultaneously to revise the drift of inertial navigation system constantly by USBL positioning.

Functional modules contain auxiliary sensor (altimeter/ single-beam probe, CTD, Doppler Velocity Log, acoustic modem, Obstacle avoidance sonar and lights etc) and survey equipment (multi-beam bathymetry, side scan sonar, sub-bottom profiler, magnetometer, water quality sensor and camera etc). Auxiliary sensor and survey equipment are comparatively speaking, which are dependent on specific objectives of surveys. The use of CTD can measure temperate salinity data of bathymetric profiles and the depth of AUVs. Altimeter can get the height from the seabed. Then AUVs navigate automatically along the planned circuit at a certain depth and height from the bottom of the sea according to altimeter and data from CTD. If there are barriers ahead, obstacle avoidance sonar will alert warning and then automatic control system will change AUVs' propulsion and heave. Acoustic modem can achieve real-time data transmission at a low rate and transfer information about AUVs' locations to LASH ship in order to acknowledge specific locations and working status of AUV, or to receive instructions to change temporarily. Nowadays, most of the marine survey equipment suppliers have developed special AUV transducers and electronic units to accommodate the limited volume and power of AUVs. Through systematic integration, automatic control system can trigger the records of controlling equipment and cruising data.

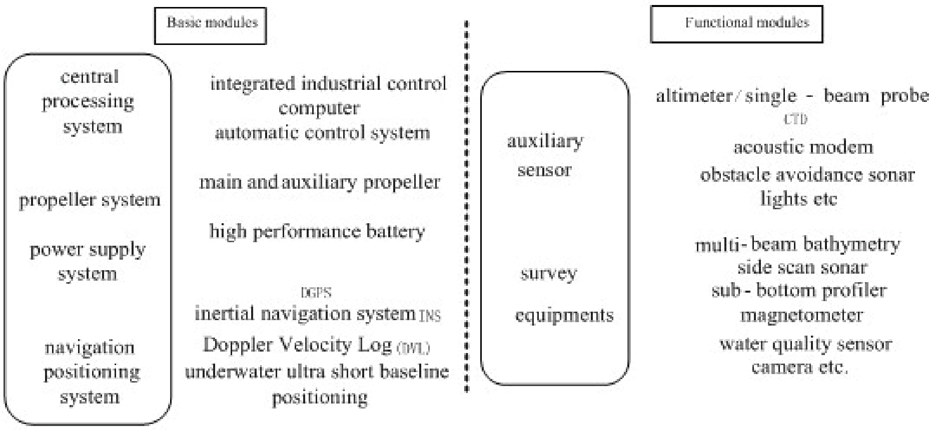

Figure 1 basic composition of AUV

The simplest marine survey AUV may only use water surface DGPS navigation positioning system plus a single-beam probe to carry out seabed topography. Take an environmental survey AUV made by a Canadian company for example, the main body of AUV dives underwater except GPS stretching out of water with a small butt for tacking water quality and so on. However, complicated AUV may use DGPS, INS, and USBL three navigation positioning system. Besides, self-contained auxiliary sensor and most survey equipment are utilized to acquire all-wave and long-term marine survey data such as marine hydrology, topology of shallow strata etc. Hugin series from Kongsberg Maritime Corporation in Norway belong to such AUVs.

AUV is a kind of compact design. Such vehicle must not only withstand tremendous pressure from deep water, but also maintain neutral buoyancy so that it can decrease the need for propelling energy and improve efficiency. A balance point should be found between the limited volume and systematic power consumption and the capacity of battery units. Different sensors should be designed to launch according to different objectives so as to maintain battery life as long as possible. Pressure resistant and water tight of AUV are also technical difficulties. The most common resolution is type "O" ring seal of electronic capsule. Sensors and pressure transducers can be sealed respectively by adopted pressure resistant materials. Some make use of one-time-forming spirals to improve strength; others may rely on compressive strength of sensors and pressure transducers themselves. Currently, a number of countries including China have been able to produce AUV resistant in 6000m water depth.

The AUV applied in oceanographic environmental survey must pay more consideration to vehicles in the running state under water medium from the aspects of design. For instance, in some large estuaries and offshore areas with strong water velocity, only flexible and powerful side impetus can make AUV go ahead within a stable speed and ensure that the survey sensor can collect effective investigation data.

4. Current commercial AUV products overseas

Starting from 1970s, various research and development projects on AUV have emerged. AUV development in early period reflects some research and military needs. Till the end of 20th century, with the development of technologies of AUV, especially advancement and popularity of automatic control system, inertial navigation system and underwater positioning system, the cost of AUV has declined to affordable levels. Meanwhile, rapid development of marine engineering industry also contributes to constantly regenerative technical methods for marine survey to adapt to more efficient and high-quality survey requirements. Some large marine survey companies pinned their hopes on the commercial prospect of AUV application, and began to cooperate with AUV research agencies and marine survey equipment suppliers. They expanded to develop and massively produce AUV at measured level. The major companies include Kongsberg Maritime in Norway, Hydroid in U.S., Bluefin Robotics Corporation in U.S. and HAFMYND Company in Iceland etc. Except that, ECA Corporation from France produces Alister AUV; YSI Corporation from U.S. makes EcoMapper AUV; ISE Company in Canada also takes part in and so on so forth.

The appearance of many AUV manufacture corporations indicates that development of various AUV technologies has already been popularized. Many international R&D institutions are still making efforts to make AUV more long-range, precise and intelligent. AUV market segments have emerged nowadays. Low-end portable AUV has already appeared in the present product line of manufacturing industry. Some high-end engineering products such as AUV-ROV integrated with the function of ROV (Remotely Operated Vehicle) will take place of current ROV with cables as an effective tool for the marine engineering construction.

Kongsberg Maritime from Norway began to develop AUV system in 1980s. It customized Hugin 3000 AUV at measured level that possesses 3000m depth of rated voltage for C&C Corporation, a marine commercial survey company in the United States. Based on that, C&C Corporation developed another Hugin 1000 AUV with 1000m depth and 3000 depth of rated voltage respectively. In the end of 2007, Hugin 4500 AUV with 4500m depth of rated voltage was produced. Because the series have good effects on marine survey, another international marine commercial survey company Fugro bought two sets of Hugin 3000 AUV later.

HUGIN（High Precision Untethered Geosurvey and Inspection System）3000 AUV is 5m in length, 1.0m diameter and 1450kg weight. Meanwhile, it integrates with Kongsberg Simrad 200 kHz multi-beam, Edgetech 120 & 410 kHz dual-frequency digital side scan sonar, Edgetech 2-10 kHz shallow bottom profiler, Seabird CTD, precision bathymetric machine, forward-looking sonar and other equipment. Aluminum oxide fuel cells are designed to drive the whole equipment. Such AUV can constantly navigate underwater within 48 hours. And additional batteries can make it extend to 60 hours 60h [2].

Hydroid in U.S. was founded in 2001. Separated from Woods Hole Oceanographic Institution, Hydroid took charge of specific maintenance and development on REMUS series AUV. At present, a whole range of product including REMUS 100, 600, 3000 and 6000 AUVs. It grows rapidly from light type such as one-man-portable to deep heavy AUV and gains a large number of orders from the military. In December, 2007 Hydroid was purchased by Kongsberg Maritime [3].

Bluefin Robotics Corporation in U.S. was built in 1997, separated from AUV laboratory in MIT. The product Bluefin-21 AUV adopts divided modular design under 4500m depth water for work. As basic configurations, it is 4.9m at length, 0.5m at diameter and 750kg at weight. Usually it can be equipped with multi-beam, side scan sonar, shallow bottom profiler, CTD and so on. The companies like Fugro and Thales have adopted such type to carry out marine survey [4].

HAFMYND Corporation in Iceland manufactured a kind of portable lightweight Gavia AUV which also adopts modular design. As basic configurations, it is 2.7m at length, 0.2m at diameter and 70-80kg at weight. Shallow and deep models possess the same shape, but different materials for pressure resistant. The new model is equipped with GeoSwath interferometer sonar, side scan sonar, shallow bottom profiler, CTD, camera etc. [5].

5. Development of domestic AUV

The study of domestic AUV design is distributed in Shenyang Institute of Automation Chinese Academy of Sciences. In 1993, the institute has developed an underwater vehicle--- “exploratory” which could dive into 1000m depth water (4.4m at length, 0.92m at width, 1.06m at height, 20kg at weight, capable to take photos under water, to scan topography measurements, acoustic modem, to transfer TV and sonogram). Shenyang Institute of Automation presided over the completion of “CR-01” AUV under 6000 depth water (4.37m at length, 0.8m at diameter, 1300kg at weight, 2.5 knots at speed, 3000 photos to be taken, 4 hours for continuous videotaping, 350m range for side scan topography and 50m thickness of ocean bottom profilers). Shenyang Institute jointed COMRA for seabed resources survey twice around South Pacific waters and gained success in 1995 and 1997 [6].

In 1999, researchers got start in developing “CR-02” AUV under 6000 depth water. Except for the same functions with “CR-01”, “CR-02” has better maneuverability, which is able to explore micro-topography of the seabed, and even track and climb the ocean floor. So “CR-02” possesses various abilities to implement deep-sea resources survey. After inspected and then approved in June, 2007, “CR-02” became another high-tech platform for deep-sea scientific investigation and exploration in China following the “CR-01”.

On July 11, 2008, the autonomous / remote monitoring system towards marine environment under the Arctic ice (abbreviated as “Arctic ARV”) independently developed by Shenyang Institute of Automation participated in China’s third Arctic expedition with “Snow Dragon”. ARV is a new concept combined the features of AUV and ROV. It can not only operate independently through the pre-programming (AUV mode) for a wide range of underwater survey, but also implement remote control (ROV mode) for a precise scope of investigation and operation [7].

Conclusions

The rapid development of offshore engineering industry urges technologies of oceanographic survey to constantly update in order to adapt to more efficient and high-quality survey requirements. With the development of various technologies of AUV, especially progress and popularization of automatic control system, inertial navigation technology and underwater positioning technology, research and manufacturing of commercial AUV by many international manufacturers have made it a popularized trend. The emergence of low-cost and lightweight AUV has opened a window for oceanographic survey by use of new technologies and methods.

Manufacturing technologies of domestic AUV is always at the forefront of the world. The successful development of “CR-02” AUV under 6000m depth water indicates that China’s AUV technologies have been perfect and China has fully mastered the key technologies of underwater robots. However, prohibitive manufacturing costs have caused giant obstacles to civilian commercial AUV. Meanwhile the monopoly of some critical sensors such as inertial navigation system and survey equipment also results in the relatively high costs.

The AUV applied in oceanographic environmental survey must pay more consideration to vehicles in the running state under water medium from the aspects of design. For instance, in some large estuaries and offshore areas with strong water velocity, only flexible and powerful side impetus can make AUV go ahead within a stable speed and ensure that the survey sensor can collect effective investigation data.

In short, easy use of AUV can significantly reduce fuel consumption of ships, which will be widely used in the future of marine survey as a cost-effective method [8]. Traditionally, research vessels conducting oceanographic survey by cruising bring huge fuel consumption. However, AUV adopting rechargeable batteries as a cost-effective method, which can significantly reduce ship fuel consumption. Consuming a small amount of power and fuel by AUV can exchange for better oceanographic data, which exerts great significance on “energy-saving and emission-reduction” advocated vigorously in China currently.

References

[1] Daniel Warren. Discovering H.M.S. Ark Royal [J]. Hydro INTERNATIONAL (ISSN:1385-4569),2004,(9):26-29

[2] Li Ye, Chang Wentian. Current status and trend of autonomous underwater vehicle [J]. Robot Technique and Application, 2007,(1):25-31

[3] REMUS 6000[DB/OL]. (2011-04-24)[2011-04-24] http://www.hydroid.com/remus6000.html

[4] Bluefin-21[DB/OL].(2011-04-24)[2011-04-24] http://www.bluefinrobotics.com/products/bluefin-21/

[5] Gavia Marine surveyor[DB/OL].(2011-04-24)[2011-04-24] http://www.gavia.is/Products/Gavia-Offshore-Surveyor/

[6] China’s second autonomous underwater vehicle in 600-meter-deep water “CR-02” has got through technical inspection [DB/OL]. (2007-06-22)[2008-09-01] http://www.sia.ac.cn/news/user/read2.php?id=1054

[7] The “North Pole ARV” participates in China’s third Arctic research expedition [DB/OL].(2008-07-30)[2008-09-01] http://www.sia.ac.cn/news/user/read2.php?id=1690

[8] Tang Minqiang. Technical comparison of deep-tow and AUV in deep water route survey [J]. Hydrographic Surveying and Charting, 2008,28(6):79-82.