Atlantis Highlights in Engineering, volume 5
International Conference on Precision Machining, Non-Traditional Machining and Intelligent Manufacturing (PNTIM 2019)

The Frame Structure of Underwater Robot for Shallow Water

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***Abstract*—In order to monitor and detect the turbid water in the shallow water channel, this paper designs a frame underwater robot. In this paper, according to the depth of diving and the thrust of the size of the frame, shell, underwater light detection, propeller and battery compartment structure distribution design, and in the end of the main stress component shell structure of the finite element analysis, design meet the requirements of the underwater robot. The frame underwater vehicle has the characteristics of simple structure and convenient manufacture.**

Keywords-Shallow Waters; Frame Type; Underwater Robot; Mechanical Structure

I. INTRODUCTION

Ocean port is a high incidence of illegal activities such as underwater ship bottom smuggling, drug trafficking and people smuggling. Especially when important political, economic and sports activities are held, the relevant adjacent waters should be closely monitored. Most of the human activities related to underwater take place in the shallow water with the depth less than 100 meters. Based on this, this paper designs a frame robot for shallow water.

In view of the mechanical structure of the robot, document 1 designs a snake-like robot prototype suitable for snaking in water, which is a mobile robot with high redundancy. Document 2 adopts streamlined underwater robot body structure design to minimize the resistance of underwater robot when it runs underwater. A new type of spherical amphibious robot structure is introduced in document 3. According to the task requirements and design indicators, a specific structure underwater robot for shallow water is designed in document 4. A kind of underwater gliding robot with bionic tail fin is designed in document 5. Literature 6 proposes a slender underwater gliding snake robot with high endurance and high mobility. Literature 7 studies the swimming of the underwater bionic frog robot, which realizes the dexterous amphibious movement with the leg-type structure. In reference 8, a bionic underwater robot based on circular long fin wave propulsion is designed. A structure design of a streamlined underwater operating robot with six thrusters and five degrees of freedom is presented in document 9.

However, the structure design of underwater robot for shallow water has the following requirements: first, it should be easy to arrange power equipment such as propeller and power supply, control box, easy to install and structure design; Secondly, it is easy to install various detection and disposal equipment. Finally, it should be easy to diagnose, maintain and replace. It is also easy to adjust the overall center of gravity and center of buoyancy as well as the resistance center in all directions, which is convenient for debugging. Although bionic underwater robot has a flexible shape and high degree of freedom, it needs to make different shape design modifications according to specific design requirements, which makes its structure design more difficult.

According to the design requirements of the underwater robot in shallow water, the overall design idea is proposed first, and then the structure design is carried out in blocks. The frame structure, shell structure, propeller structure, lamp detection and battery cabin structure are designed and selected respectively, and then the connection of the mechanical structure is sealed. Finally, due to various influencing factors in the underwater environment, finite element analysis is needed for the shell head of lightweight materials.

II. UNDERWATER ROBOT STRUCTURE AS A WHOLE

The underwater robot shall have a depth of not less than 30m and a thrust of not less than 1Kg. The underwater robot used in shallow water is different from the robot used in deep sea. The frame structure greatly reduces the pressure and resistance of the robot when it is under the water. Its principle is easy to assemble, can mount propeller, camera, lighting and other peripheral equipment; Easy to adjust the center of gravity, center of buoyancy and resistance in all directions.

In design, the idea of modularization of equipment in the shell of the carrier. The observation lighting system is installed in the head to provide light source to meet the needs of the camera function. The power module is in a separate battery compartment, while a series of necessary modules such as shell sensors, instruments and equipment are sealed inside the shell. In order to reduce the development cycle and the risk in the design, the motor and propeller with mature technology are adopted. Underwater robot must possess forward, backward, turn left and right, up and down movement condition, therefore, to promote power module driven by two horizontal and two vertical driver: two horizontal thrusters arranged in the robot motion in horizontal direction, on the back of the robot, left for underwater robot, backward and forward, to the right to exercise the enough power, two vertical thruster arrangement in the intermediate position of the underwater robot framework of ontology, near for underwater robot up and down movement of the enough power.

III. FRAME STRUCTURE

The characteristic of the frame underwater robot is that it has an anti-collision frame. When the control signal is out of control and the water flow is suddenly changed, the anti-collision frame shows its importance to prevent damage to the internal components of the robot. Its front end and back end are circular arc design, which can reduce the underwater resistance of the forward and backward auv. The upper, lower, left and right sides are planar design, and the underwater resistance is relatively large when running in these four directions, so it is suitable for slow propulsion.

IV. SHELL STRUCTURE

For ease of assembly and maintenance, the robot's head is designed as a detachable structure, namely the robot by the main shell is the main design modelling of the head and acrylic glass of two parts, the main for the cylindrical shell, as the fixed shell of underwater robot, also is the main location, installation of various sensors and instruments in the intermediate position of the main module to install cameras, will be the main module and the acrylic glass connected with screw as camera protection shell. In order to reduce the weight of the AUV, the material should reduce the thickness of the shell as much as possible to reduce the overall weight under the condition of underwater compressive resistance. Therefore, in the design of the main shell with relatively light weight, good corrosion resistance, production is relatively simple, relatively easy to repair 4032-T6 aluminum alloy material production. The structure diagram of the main shell is shown in figure 1.

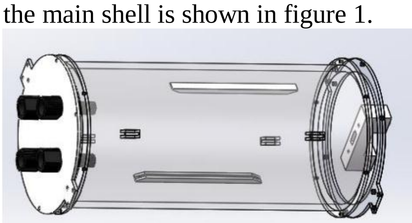

Figure 1. Head shell structure

The acrylic camera protects the glass cover in the shape of a spindle, which reduces the stressed area and the robot's underwater resistance. Acrylic glass cover is shown in figure 2.

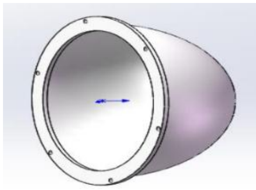

Figure 2. Acrylic glass cover

V. PROPELLER CONSTRUCTION

Two propellers control the advance and turn of the robot. When the two propellers move in the same direction at the same speed, the robot can move forward in a straight line. When operating two propellers at different speeds in opposite directions, the robot can move in place. When manipulating two propellers at different speeds, the robot can turn at any radius. Two vertical propellers control the rise and fall of the auxiliary robot.

This paper requires that the thrust should not be less than 1kg, and the standard screw propeller should be selected. The thrust of a single propeller should be 1kg~4kg, and the thrust of two horizontal propellers should be 2kg~8kg, which meets the design requirements. When an auv is sinking in water, the weight of the robot body is required to be greater than the buoyancy of water. According to Archimedes' law: F float =G row = p water V row G. Therefore, when the robot is sinking, the force received is greater than the buoyancy. At this time, F float =G row. Two propellers are designed in the vertical direction to assist the robot in sinking. The propeller adopts modular design, and the structure of the power propeller is shown in figure 3.

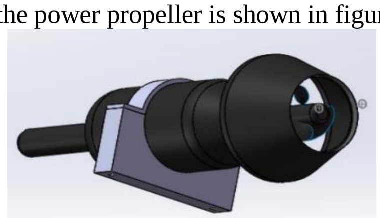

Figure 3. Propeller construction

VI. LAMP DETECTION

Since the water quality in shallow water is generally cloudy, it is very difficult to detect the target's lighting. The water depth is basically not visible below 0.5 meters. In order to work in the murky water, special lighting and detection equipment must be used. Observed in order to ensure that the target had enough illuminance, choose 3000K color temperature of HID xenon lamp, its radiation for golden light, a lot of use of the color of the light reflection is not easy to water molecules, it has strong penetrating power, in negative situations, such as fog, rain, water, lighting effect is very outstanding, more suitable for use underwater. In order to obtain the best camera effect, adjust the exit Angle of the two lights and the best position of the camera's field of view Angle and fix it. Camera and floodlight are located on the same head, can be left and right up and down deflection.

VII. BATTERY COMPARTMENT STRUCTURE

The structure of the battery compartment is mainly based on the shape of the battery. The battery compartment shall be well sealed and no leakage shall be found between the cabin and the external wiring. The structure of the battery compartment is shown in figure 4.

Figure 4. Battery compartment structure

VIII. OVERALL STRUCTURAL ARRANGEMENT

After the design of the structure and shape of each part of the underwater robot, the overall mechanical structure layout of the frame underwater robot is obtained by adopting a more reasonable spatial layout and an appropriate design of mass distribution, as shown in figure 5.

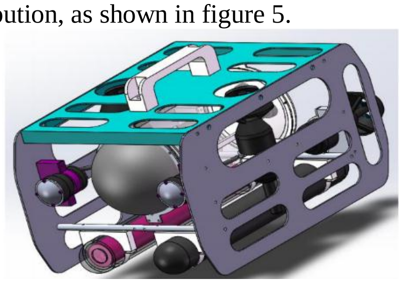

Figure 5. Overall structure layout of frame underwater robot

IX. THE SEAL OF THE AUV STRUCTURE

The shell of the pressure-resistant underwater robot is equipped with necessary instruments for underwater detection and highly precise electronic equipment, etc. When the underwater robot completes its task underwater, it should carry out detailed inspection and maintenance on each part. Therefore, the seal between the detachable head and the shell is quite important. Because the design, manufacture and processing of O-ring seal model have been standardized and serialized by the industry, all sealing devices of the underwater robot shell structure adopt relatively mature O-ring seal technology. Radial seal and axial seal are used to seal between the head shell and acrylic glass cover.

In order to check the sealing performance and safety performance of the AUV before launching, it is necessary to leave an opening on the shell to check the air tightness. The size and size of the opening must be completely consistent with the interface designed by the standard pressure gauge. The air tightness can be judged by comparing the internal pressure with the external pressure.

X. FINITE ELEMENT ANALYSIS OF SHELL HEAD

In the design of the underwater robot, the most important part is the lightweight shell with the head, which includes sensors, data collectors, video transmission and other main parts. Therefore, it is necessary to check the anti-pressure and stress of the part of the shell. The shell of the head is made of plexiglass. The thickness of the shell is 10mm. The yield strength of the plexiglass at normal temperature is 77.2Mpa, the elastic modulus is 532.7Mpa, and the poisson's ratio is 0.5. Other materials are 4032-T6 aluminum alloy, which has high corrosion resistance and compression resistance, meeting the requirements of the underwater robot. In this paper, the submersible depth of the underwater robot is required to be at least 30m. When it is located at the seabed of 30m, the pressure is:

$$P = \rho g h = 1.0 \times 10^3\, kg/m^3 \times 10\, N/kg \times 30m$$
$$= 3.0 \times 10^5 = 0.3Mpa$$

Take the safe underwater pressure as 0.5Mpa, and check the formula:

$$\mathrm{P_j} = \mathrm{nP_G} \tag{1}$$

In equation (1),

P_j is the pressure used to calculate the strength;

n is the safety factor, generally 1.0~1.5, here 1.2;

According to formula (1), P_G is 0.6Mpa.

Finite element analysis of the shell design is performed in Solidworks, as shown in figure 6.

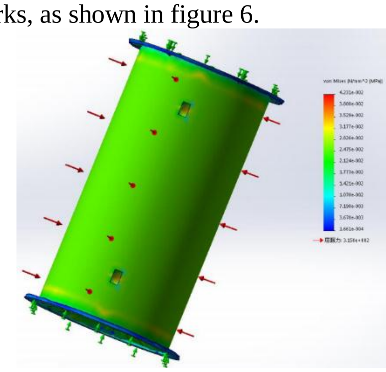

Figure 6. Finite element analysis of shell

As you can see from figure 6, the stress of the base of present uneven distribution, from middle to both sides have different color changes, but near the fixed part of the yellow area is more, the stress is larger, the big stress on the parts near the end, its value is 3.117e-002, and the material yield limit of 3.15e+002 parts, its stress is far less than the yield limit. Therefore, the selection of shell material meets the requirements.

XI. ANTI-CORROSION MEASURES FOR UNDERWATER ROBOTS

Because the underwater robot needs to work underwater for a long time, it must pay attention to the problem of anti-corrosion in the underwater environment. In view of the corrosion of the AUV, the following measures are adopted to reduce the corrosion:

1) Conduct oxidation treatment on the surface of the shell of the AUV.

2) Apply anti-corrosion paint on the oxidized shell surface.

3) After each launching work, wash the underwater robot with fresh water to reduce the corrosion of microorganisms attached to the shell.

4) Spare parts for corrosion-prone parts and components for regular replacement.

XII. CONCLUSION

In this paper, the structure of the underwater robot is determined as a whole, and then the detailed design is carried out according to the functions of each part, including the design of detection lighting, battery compartment and propeller. Then to the overall design, the design of each part after the overall assembly. Because its working environment is underwater, the sealing of the shell and the whole anti-corrosion of the underwater robot are improved. When the robot moves underwater, it will be subjected to the resistance and pressure caused by the impact of water flow. Therefore, finite element analysis of the shell is carried out, which meets the requirements. In the future application of the frame underwater robot, the manipulator claws and sonar installation can be added to further enrich and improve its functions.

ACKNOWLEDGEMENT

Thanks for the fund project: Shaanxi Science and Technology Coordination Plan (2015KTZDGY-02-01); Xi'an Weiyang District Science and Technology Plan (201837, 201840).

REFERENCE

[1] Xie Yafei, Lu Zhenli, Xu Huigang, Borovac Bronislav, Li Bin. Mechanism Design and Meandering Research of Underwater Snake Robot [J]. High-tech Communications. 2016, 26(06):599-605.

[2] Song Sili, Liu Tiantian, Kang Kaican, Chen Yanjun. Design and Implementation of Mechanical Structure of Autonomous Underwater Robot [J]. Robotics Technology and Application, 2012(04):26-29.

[3] Wu Guoqiang. Stability Analysis of Spherical Amphibious Robot [D]. Tianjin University of Technology, 2017.

[4] Li Zuoxin. Design and Motion Control of Small Underwater Vehicle Carrier [D]. Shenyang University of Technology, 2019.

[5] Wang Qishan. Mechanism Design and Hydrodynamic Analysis of Underwater Bionic Gliding Robot [D]. Lanzhou Jiaotong University, 2015.

[6] Tang Jingge, Li Bin, Chang Jian, Wang Cong. Structural Design and Dynamic Modeling of Underwater Gliding Snake-like Robot [J]. Journal of Huazhong University of Science and Technology (Natural Science Edition), 2018, 46(12):89-94.

[7] Zhang wei. Research on bionic frog robot and its trajectory planning [D]. Harbin Institute of Technology, 2017.

[8] Yan Yongcheng, Wang YangWei, Lan Bowen, Zhao Dongbiao. Design of Bionic Underwater Robot Based on Annular Long Fin Wave Propulsion [J]. Machinery Manufacturing and Automation, 2018, 47(01):166-169.

[9] Zhang Zhiyuan. Structural Design and Hydrodynamic Research of Five-degree-of-freedom Underwater Robot [D]. Harbin Engineering University, 2017.

[10] Chen Shiyong, Wang Litao, Lu Jinfu,Tang Zhenyu . Mechanical Structure of A Frame-shaped Underwater Robot [J]. Journal of Guangzhou Institute of Navigation, 2017, 25(01):22-23+35.

[11] S. Guo，Y. He，L. Shi, S. Pan, R. Xiao, K. Tang and P, Guo, "Modeling and experimental evaluation of an improved amphibious robot with compact structure", Robotics and Computer–Integrated Manufacturing, vol. 51, pp. 37-52, 2018.

[12] Kim, Jung-Yup.Design of six-legged walking robot, Little Crabster for underwater walking and operation. Advanced Robotics, v 28, n 2, 2014:77-89.

[13] Jun, Bong-Huan, Lee, Pan-Mook, Jung, Yong-Hwa.Experience on underwater artefact search using underwater walking robot Crabster CR200 [A]. Oceans , 2016 :1-5.

[14] Zhang Shihao, Wang Wenliang, Han Peng, Zhao Bin. Design and Simulation of Bionic Manta Ray Robot [J]. Mechanical Engineer, 2019(06):147-151.

[15] Yan Xingya. Simulation and Experimental Study on Autonomous Swimming of Imitation Crab Robot [D]. Harbin Engineering University, 2017.