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The conception and exploration of the underwater vehicle simulator

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The conception and exploration of the underwater vehicle simulator

Gong Shao-feng[1,2,a*],Zhang Jian-bin[1,2,b],Cheng Dong[1,2,c], Xiao Hai-Yan[1,2,d], Dong Ping[1,2,e],WU Zhan-sheng[3, f]

[1]713 Research Institute of China Shipbuilding Industry Corporation, Zhengzhou, Henan, China.

[2]Henan Key Laboratory of Underwater Intelligent Equipment, Zhengzhou, Henan, China.

[3]The 91515 Army, SanYa, China.

[a]email: 13838566372@163.com , [b]email: zjb66688@163.com, [c]email: 315257215@qq.com, [d]email: xiaohaiyan@yahoo.com.cn, [e]email: dong-ping@mail.ustc.edu.cn, [f]email: 309421663@qq.com

*Corresponding author: [a]email: 13838566372@163.com, wlzx@csic713.com.cn

Abstract: In this paper, a new type of underwater vehicle simulator is proposed. The underwater vehicle simulator adopts capsule prefabrication structure and can be carried on UUV. Each UUV can be loaded with multiple underwater vehicle simulator capsules. After sailing to the predetermined location, long-distance delivery is carried out. After the underwater vehicle simulator is fully charged and expanded, the underwater vehicle simulator cluster is formed to achieve tactical purposes such as confusing and inducing enemies in quantity, orientation and deployment. The technology can be applied to the new generation of underwater vehicle safety defense system, and can be popularized and applied to other weapon systems. It has great military, political and national defense significance and has broad application prospects.

1. Introduction

In modern land war, inflatable simulated vehicles, airplanes, artillery, materials, warehouses, personnel and other rubber prostheses are often used, so as to achieve the purpose of confusing and inducing enemies in quantity and deployment. In World War II, before the Allied army landed in Normandy, in order to confuse the German army, the Allied army stationed a large number of ‘troops’ on other coasts. In the barracks of these ‘troops’, most of them were fake equipments that could not fire, but they also greatly contained the firepower of the German Army and provided help for the successful landing of Normandy. In 1950s, the United States put forward the concept of launching flying bait devices from the air. The U.S. Air Force received the first batch of officially equipped bait missiles in 1960[1]. In the US-Iraq war, Iraq set up a large number of inflatable tank models and tents under the condition of air control being controlled, which successfully attracted the firepower of the US Army and reduced the loss. Therefore, the simulation camouflage technology is of great significance no matter in the past or now. The inflatable tank model is shown in Fig1.

(The left side is a real tank, and the right side is a fake tank)
Fig.1 The inflatable tank model

However, in underwater combat, especially for the large-volume underwater vehicle, if the rubber prosthesis inflation technology is adopted, under the action of buoyancy, the inflatable underwater vehicle prosthesis will soon float out of the water and cannot be suspended in the water, thus losing the combat effect. Therefore, the current underwater vehicle usually uses bait bomb to simulate the underwater vehicle signal and induce the enemy's wrong target to launch an attack[2].

However, with the rapid progress of weapon equipment technology, various detection methods and data analysis technologies emerge in endlessly. The existing induction technology cannot simulate the shape of underwater vehicle. Once the signal induction technology is cracked by the enemy, or the underwater vehicle is not detected at the signal sending place, it is confirmed as a false signal, and the bait bomb will lose its practical significance. Therefore, it is necessary to develop a new type of holographic induction technology for underwater vehicle, which not only simulates the underwater vehicles on the signal, but also simulates the underwater vehicles on the form to achieve the effect of false chaos, at the same time to realize the deep sea remote self-flight control, so that the induction effect is better, the underwater navigation entity is more hidden[3].

2. Overall research ideas

In order to solve the problem that the existing underwater navigation inflatable simulation technology cannot stay in water, the existing rubber inflatable technology cannot be adopted. Under the action of water buoyancy, the inflatable underwater vehicle prosthesis will soon float out of the water and cannot be suspended in the water. It needs to adopt dynamic balance technology of weight and buoyancy to ensure the normal suspension of underwater vehicle simulator after expansion. At the same time, the existing induction technology cannot simulate the shape of underwater vehicle. Once the signal induction technology is cracked by the enemy, or the underwater vehicle is not detected at the signal sending place, it is confirmed as a false signal, and the bait bomb will lose its practical significance. The existing underwater shape simulation technology of underwater vehicle is still blank.

In order to solve the above problems, it is necessary to put forward the technical scheme of deep-sea long-distance self-propelled holographic induction underwater vehicle simulator, which has the ability of holographic simulation induction of electric, acoustic signals and entity shape, and has the ability of suspension in water and long term induction, and has the ability of long-distance self-flight delivery in deep sea, and has the ability of cluster control and multi-point delivery, carry out the following research:

a) The research on the overall scheme of holographic induction technology for deep-sea long-distance self-propelled underwater vehicle

Focusing on the working principle and functional characteristics of holographic induction technology of deep-sea long-distance self-propelled underwater vehicle, carry out the demonstration of technical indicators and approaches, and carry out the planning of research contents and the decomposition of key technologies.

b) The research on holographic skeleton structure and support forming technology

Research the main body skeleton material, structure composition, holographic form of underwater vehicle simulator, research skeleton loading, separation technology from vehicle, research skeleton stacking, and water expansion forming technology.

c) The research on nano holographic outer membrane and integrated induction technology

Research underwater navigation signal water detection, photoelectrics, shape simulation technology, research ultra-thin nano film material, shape, research the holographic simulation technology of ultra-thin nano film surface coating, and research the holographic induction technology of the integration of shape, sound and electrical signals.

d) The research on underwater charging technology of simulator

Research the underwater charge energy, charge materials, miniaturization of charge structure and separation technology after charge of simulator.

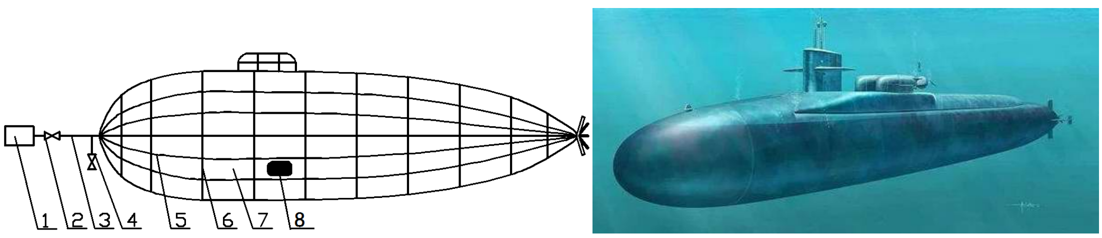
e) The research on underwater fixed depth suspension technology of underwater vehicle simulator

Research the variation rules of vector characteristics, buoyancy and so on in the underwater charging process of underwater vehicle simulator, and research the suspension principle and buoyancy adjustment structure.

f) The research in long-distance defense technology in deep sea

Research the simulator delivery mode, research UUV loading, underwater navigation technology and the pre-delivery of vehicles, multi-directional control technology.

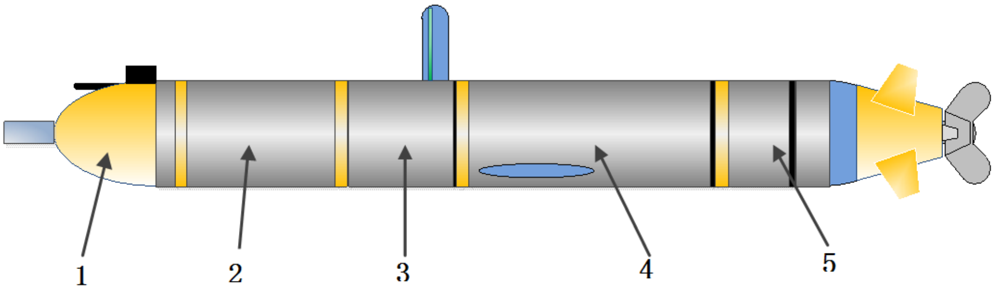
According to the overall design idea, applying theories and methods such as aerodynamics, fluid dynamics and structural mechanics, the development of underwater vehicle simulator is carried out. The underwater vehicle simulator consists of power charging device, one-way valve, charging pipeline, internal and external pressure balance valve, main skeleton, secondary skeleton, shape membrane and signal generator. When it is not working, it is prefabricated into a capsule shape, which is convenient to carry on underwater vehicles such as UUV. When working, the simulator can be charged and expanded to form the framework of the underwater vehicle simulator according to the established shape. At this time, the shape membrane connected on the skeleton unfolds to form the outer outline of the underwater vehicle simulator, while seawater enters the interior of the underwater vehicle simulator through the gap between each shape membrane, filling up the interior space, and finally forming a shape similar to the real underwater vehicle. The holographic induction technology of deep-sea long-distance self-propelled underwater vehicle can be used for long-distance delivery, and can simulate the shape of the real underwater vehicle and send out the induction signal, to achieve tactical purposes such as confusing and inducing enemies in quantity, orientation and deployment, etc, and to improve the concealment and survival ability of underwater vehicles. The structure diagram of the simulator is shown in Fig2.



1- power charging device, 2- one-way valve, 3- charging pipeline, 4- internal and external pressure balance valve, 5- main skeleton, 6- secondary skeleton, 7- shape membrane and, 8- signal generator

Fig.2 The structure diagram of the simulator

3. The capsule long-distance delivery technology of underwater vehicle simulator



1-head, 2-vehicle simulator, 3-navigation equipment cabin, 4-energy cabin, 5-propulsion system cabin
Fig.3 The structure diagram of the underwater vehicle simulator mounted on UUV

The underwater vehicle simulator adopts capsule prefabrication structure and can be carried on UUV. Each UUV can be loaded with multiple underwater vehicle simulator capsules. After sailing to the predetermined location, long-distance delivery is carried out. After the underwater vehicle simulator is fully charged and expanded, the underwater vehicle simulator cluster is formed to achieve tactical purposes such as confusing and inducing enemies in quantity, orientation and deployment, etc. When using the underwater vehicle simulator, the underwater vehicle simulator is carried with UUV and other carriers to transport to the designated position (see Fig3), put the underwater vehicle simulator into the sea according to the instruction. After receiving the task instruction, the power charging device starts to fill the rubber tube with high-pressure gas or seawater. The rubber tube expands under the action of water pressure, and forms the framework of underwater vehicle simulator according to the specified shape. At this time, the shape membrane connected on the skeleton unfolds to form the outer outline of the underwater vehicle simulator, while the seawater enters into the interior of the underwater vehicle simulator through the gap between each shape membrane, filling up the interior space, and finally forming the shape similar to the real underwater vehicle, then separates the one-way valve from the power charging device, and puts the underwater vehicle simulator into the established position in the sea[4].

The first stage: load the underwater vehicle simulator into UUV and other navigators, which can reach the port through land transportation, sea transportation, air transportation and other forms.

The second stage: the deployment stage. UUV installation is deployed in the mother ship sails to the deployed sea area.

The third stage: the deployment stage. The operator controls the UUV carrier of the mother ship to release UUV.

The fourth stage: the departure stage. The operator transmits the command to UUV, and UUV changes to autonomous mode.

The fifth stage: the task execution stage.UUV goes to the task execution area through the preset path to carry out the deployment task of the underwater vehicle simulator. After the underwater vehicle simulator is fully charged and expanded, the underwater vehicle simulator cluster is formed.

The sixth stage: the recycling stage. After the task is finished, the underwater vehicle simulator will be captured by underwater robots, trawls, etc, and then be recycled to the mother ship.

4. The full-scale skeleton structure and support forming structure

The simulator uses the fine rubber tube which can be filled with water as the skeleton, forming the interlaced network structure of longitude and latitude. The density of the rubber tube is close to that of water. A layer of shape film composed of several very thin rubber films is connected to the outside of the rubber tube, and the shape film is sprayed with the same material as the real underwater vehicle, and there is a certain gap between each shape film. A one-way valve is set on the main inlet pipe of the rubber tube as the interface with the water filling equipment. At the same time, it also plays a role in preventing the water in the rubber tube from overflowing. A safety valve is connected to the main inlet pipe to prevent the pipe from being damaged due to the excessive pressure difference between the pipe of the underwater vehicle simulator and the external environment during the process of water filling. When not filled with water, the rubber tube and rubber film can be folded together for easy storage and transportation. The structure is shown in Fig4.

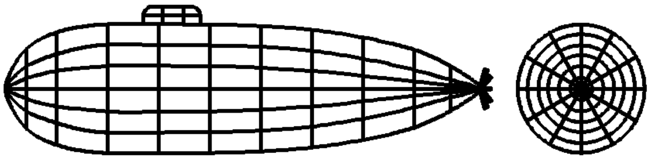


Fig.4 The full-scale skeleton structure and support forming structure

The size of the skeleton structure and support forming structure can be adjusted according to the size of the simulated underwater vehicle. The rubber tube used in the skeleton structure and support forming structure has certain elasticity, which can be used together with the internal and external pressure balance valve to ensure the internal and external pressure balance, and the structural damage will not be caused by the excessive internal and external pressure difference when it is put in and unfolded in a large depth. Meanwhile, it can conduct independent pressure balance with the change of water depth.

5. The power charging device

The power charging device uses the gas generator as the gas source, mainly because the gas generator is small in size and simple in structure. It is usually solid and easy to carry. After working, the gas production is large and the inflation speed is fast.

Considering the bearing capacity of domestic rubber products to high temperature at present (currently the thin rubber pipeline can achieve temperature resistance of about 250°C), the inflation temperature of the gas generator should be lower than 200°C. However, the temperature of the gas generated by the low-temperature gas generator is generally around 900°C. In order to meet the requirements of low-temperature inflation of rubber, the high-temperature gas generated by the gas generator must be cooled to make a low-temperature gas generator, and the generator must have a certain working duration. Therefore, solid propellant with low burning temperature and low burning rate should be selected as the basic gas-producing grain[5].

There are two ways to generate low-temperature gas: one is the cold gas method, which uses high-pressure gas cylinders to store cold gas, and uses cold gas to inflate tuber pipelines. Cold gas can be inert air, nitrogen and so on. The second is the got gas method, which uses the solid gas generator to generate hot gas to directly inflate the rubber pipeline, and the carrier of the gas source is solid propellant.

The above two methods have their own advantages and disadvantages. The advantage of the air-conditioning method is that the gas is air-conditioning, which is stored in a high-pressure cylinder and can directly inflate the rubber pipeline. The method is simple and convenient, the technology is mature, and the realization is less difficult. However, the air-conditioning method requires high-pressure gas cylinder to store gas, and high-pressure gas cylinder needs larger volume and weight. The main advantages of the hot gas method are that solid propellant is used as the gas source, with small volume and light weight. However, the gas generated by the hot gas method is hot gas with high temperature, while the rubber pipeline cannot resist high temperature. Therefore, it is necessary to cool the hot gas before aerating the rubber pipeline.

Through analyzing the characteristics and properties of the task, according to the requirements of the design task, under the condition that both size and weight are required, the hot gas method is decided.

Selection of gas source types

As a gas source, solid propellant requires that the temperature of the gas is low. Before the gas is inflated into the rubber pipeline, it needs to go through the cooling room to cool down. The distance of gas flowing through is short, so it is required that the amount of gas generated should not be large, otherwise, the heat transfer and cooling effect of gas is not good. Therefore, low burning rate propellant should be adopted.

The selection principle of propellant is:

a) It has the energy characteristics as low as possible and requires low combustion temperature of propellant.

b) It has the density as high as possible and produces a large amount of gas, which is conducive to reducing negative quality.

c) It has good interior ballistic performance, and requires low burning rate of propellant, small pressure index, and the temperature sensitivity coefficient of propellant should be as small as possible, which can adapt to different initial temperature, combat areas and seasons.

d) It has good combustion stability, low critical pressure of normal combustion and little influence on erosion combustion.

e) It has good mechanical properties, can withstand large impact, vibration and accelerated overload, and solid grain cannot have cracks and debonding.

f) It has good chemical stability, natural decomposition of propellant during temperature change and long-term storage, stable chemical composition and insensitivity to water and humid environment.

g) It has good safety and explosion in production, use, transportation, storage, operation and daily maintenance, with maximum safety.

h) Good economy, suitable for mass production, low cost, and can be used in large quantities.

Common solid rocket motor propellant: double base propellant, composite propellant and modified double base propellant.

The double base propellant has low specific impulse and a high pressure index. The burning rate is greatly affected by the pressure change and the internal ballistic performance is not good enough. However, the double base propellant has high strength, low glass transition temperature and good mechanical properties. It can be continuously produced in large quantities and is mostly used for small rockets and roll boosters.

The composite propellant has high specific impulse, poor mechanical properties, large hygroscopicity and great influence on initial temperature. It mostly adopts wall-mounted pouring structure, which is easy to cause thermal stress after curing and makes the grain produce cracks and debonding. Composite propellant is widely used in solid engines.

The modified double base propellant is based in double base propellant, adding oxidant and metal powder to improve specific impulse.

Comprehensive consideration of low temperature gas generator technical index requirements, working conditions, production costs and other factors, through investigation, the composite solid propellant with low burning rate and low burning temperature commonly used in current domestic is adopted.

The low-temperature gas generator is actually a solid rocket engine, which is mainly composed of solid propellant grain, combustion chamber shell, nozzle, ignition device and cooling room. After the thermal gas generated by it is cooled by the expansion of the nozzle, it passes through a cooling room, and after the thermal gas is cooled, it inflates into the rubber pipeline.

The gas cooling device adopts the structure of the cooling room which is multiporous throttling expansion to extend the gas flow route. There are two methods of cooling the gas: physical method and chemical method. The physical method is to use cooling water or metal wire with large heat volume to absorb the heat of the gas flowing through its surface, so as to cool the gas. The chemical method is to use the chemical agent of heat absorption reaction to absorb the heat of the gas on its surface, so as to cool the gas. Based on working stability and cost considerations, cooling water is used as coolant in this study[6].

The length, quality, inflation time, ignition delay time and installation of the gas generator are all strictly limited, so the overall structure of the gas generator should be compact, the internal dimensions should be coordinated with each other, and the external connection should meet the installation requirements.

For the shell material of small size gas generator, metal material is mainly used. Metal materials have low cost and convenient processing, which are suitable for mass production and use. Metal materials can use high-strength steel. Formal products can use titanium alloy or aluminum alloy from the aspects of corrosion resistance and light weight. After comprehensive consideration, the principle prototype of the gas generator adopts high-strength alloy steel 30CrMnSiA and its mechanical properties are as follows:

Strength limit: σ_b=1080MPa

Yield limit: σ_s=885MPa

Elongation: δ>10%

Density: ρ_c=7.76g/cm^3

In order to increase the heat exchange time between the gas and the cooling agent, the cooling room is divided into two chambers, and the gas keeps the supersonic flow at the outlet of the first chamber to conduct the second supersonic expansion and cooling. Therefore, the throat diameter of the first chamber nozzle must be appropriate. If the throat diameter is too large, supersonic flow cannot be formed. If the throat diameter is too small, shock waves will be generated in the throat of the engine, which will affect the normal operation of the engine[7]. The structure of the gas generator and cooling room is shown in Fig 5.

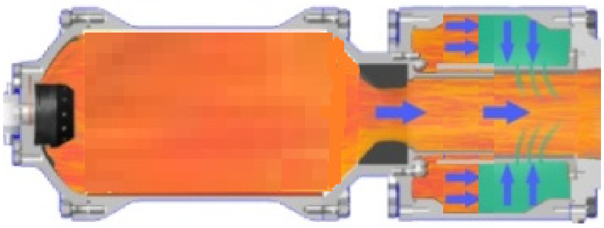


Fig.5 The structure of the gas generator and cooling room

The energy calculation equation of the working process is:

$$P_c = [\rho_p \cdot u0 / P_0^{\nu} \cdot [1+\alpha_T (Ta - T0)] \cdot C^* \cdot \frac{Ab}{\sigma_f A_t}]^{\frac{1}{1-\nu}} \quad (1)$$

$$m_g = \frac{g \cdot A_t \cdot \sigma f}{C^*} \int_0^t P_c dt + m_{g0} \quad (2)$$

$$m_l = \mu s_l \sqrt{2g\rho\lambda} \int_0^l \sqrt{P_c} dt + m_{l0} \quad (3)$$

$$X_e m_g C_{vg} t_{vg} + m_l C_l t_l + m_r C_{vr} t_r = U_2 + \frac{1}{2} Mv^2 + \int_0^1 Fdl \quad (4)$$

In the formula, P_c is the pressure of the gas generator, ρ_p is the density of grain, $u0$ is the burning rate of grain, α_T is the temperature sensitivity coefficient of grain, Ta is the initial temperature, c^* is the characteristic speed of grain, Ab is the combustion surface, σ_f is the total pressure recovery coefficient, A_t is the cross-sectional area of the nozzle, ν is the pressure index of grain, μ is the flow coefficient, s_l is the cross-sectional area of the water spray hole, ρ is the density of water, λ is the pressure differential coefficient of water spray, $X_e m_g C_{vg} t_{vg}$ is the initial energy of gas, $m_l C_l t_l$ is the initial energy of cooling water.

6. The test verification

After scheme demonstration and technical design, the underwater vehicle simulator has completed the land joint inflation test and underwater principle test, the main purposes of which are as follows:

a) Examine the rationality of the scheme, function and structural design of the whole device, and verify the working stability and reliability of the underwater vehicle simulator.

b) Examine the structural integrity of the underwater vehicle simulator after inflation, and measure the gas temperature in the underwater vehicle simulator.

c) Measure the gas pressure in the underwater vehicle simulator and examine the rationality of the grain quality of the gas generator.

d) Check the exhaust function of the internal and external pressure balance value.

The first land test because the internal and external pressure balance valve exhaust too fast, the underwater vehicle simulator open abnormal, through the internal and external pressure balance valve structure improvement and spring adjustment, the second and the third land inflation test meets the design requirements. The generator works normally and the simulator opens normally. The test situation is shown in Fig 6.

Fig.6 The simulator land test

7. Conclusions

In this paper, a new type of underwater vehicle simulator is proposed, which has the advantages of small initial volume, fast speed, good simulator effect, long control distance and large applicable depth, and has obtained the invention patent authorization. The simulator not only simulates the underwater vehicle on the signal, but also simulates the underwater vehicle on the form, which can achieve the effect of false chaos, and at the same time realize the long distance self-navigation control of the deep sea, make the induction effect better, and make the underwater vehicle entity to be protected more hidden, so as to achieve the purpose of confusing and inducing enemies in quantity, orientation and deployment. The research results can be applied to the new generation of underwater vehicle safety defense system and underwater UUV technology, and can be popularized and applied to other weapon systems. It has great military, political and national defense significance and has broad application prospects.

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