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An Expanding Graded Suction and Capture Mechanism

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Abstract

In recent years, with the improvement of people's living standards, the large demand for sea cucumber has promoted the rapid development of the sea cucumber breeding industry, making it an important industry for fishermen in northern coastal areas of China to achieve increased fishing efficiency and income. However, investigations have found that the current sea cucumber fishing method is still mainly traditional manual fishing. Several existing semi-automatic sea cucumber fishing devices have problems such as complex operation, high cost, difficulty in maintaining stable posture in marine environments where currents, ocean currents, and waves are common, and low fishing efficiency. In this context, this article is committed to researching and designing an automated sea cucumber fishing device, which, through the coordination and cooperation of various parts, completes the identification, positioning, and fishing operations of underwater sea cucumbers.

Keywords

Sea cucumber fishing robot, Shallow waters, Suction and capture system,overall design.

1. Introduction

According to the 2023 National Economic and Social Development Statistics Bulletin of Shandong Province, the total output of aquatic products (excluding the output of deep-sea fisheries) was 8.768 million tons, an increase of 3.9%. Among them, the production of seawater products reached 7.533 million tons, an increase of 3.9%. The coastline of Shandong Province accounts for 1/6 of the total length of the country, and the total length of Weihai coastline is 986 kilometers, accounting for about 1/3 of Shandong Province and 1/18 of the total length of the country. The map of Weihai is shown in Figure 1. The total area of Weihai nearshore waters is 11449 square kilometers, of which the total area of shallow waters below minus 20 meters is 3482 square kilometers, accounting for 30.4% of the total area.

At present, sea cucumber fishing can only be obtained through manual fishing, which involves the safety of divers and specially designed equipment. Divers need to use tools to collect sea cucumbers from rocks or sand bottoms on the seabed to ensure that the collected sea cucumbers meet quality requirements [2], and the fishing process will not have a serious impact on marine ecology. This requires high requirements for divers engaged in sea cucumber fishing, and their work risks are also high, making them prone to lung diseases. With the advancement of technology and the increasing emphasis on the sustainable utilization of marine resource shells, people have begun to explore other fishing methods to reduce the life risks of divers and improve fishing efficiency.

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2. Underwater robots for sea cucumber fishing

With the development of technology, underwater robots have been widely used in the field of sea cucumber fishing. Remote controlled underwater robots (ROVs) are an important branch of underwater robots, which are widely used and have high technological maturity. They can use umbilical cables to transmit power and communication. Easy to operate, flexible to operate, and cost-effective, it can replace manual operations in extreme underwater environments such as underwater archaeology, sunken ship salvage, and marine resource collection.

For the aquaculture industry, robots are required for high efficiency and high fishing volume. Related fishing type ROVs often adopt an open rack structure to carry marine organism collection systems. The collection and storage devices are the key points in the design of these types of ROVs [3], which can be roughly divided into two categories: robotic and suction. The specific comparison between robotic and suction collection devices is shown in Table 1.

Table 1 Comparison of advantages and disadvantages of collection device schemes

Plan Name	Fishing rate	Sea Cucumber Damage	Control Difficulty	Occupy Space	Production Cost
Mechanical Arm Collection Device	low	high	high	small	high
Suction Collection Device	high	low	low	large	low

2.1. Robot arm type underwater fishing robot.

The robotic sea cucumber fishing robot mainly uses the robotic arm as the grasping mechanism to collect targets, as shown in Figure 1. During the grabbing process, hovering operations are generally required. When the seabed water flow is fast, it poses a great challenge to the motion control system of underwater robots. In addition, in order to avoid damage to the surface of marine organisms, non-destructive grabbing mechanisms are a key point of related research [4].

Figure 1 Robot arm fishing for ROV

2.2. Sucking Underwater Fishing Robots.

The principle of suction fishing is based on the negative pressure principle [5], which completes suction fishing by changing the internal flow field of the channel and forming negative pressure from the outside. The most common tool in the fishing industry is the fish suction pump, as shown in Figure 2, which is characterized by simple operation, high work efficiency, and low fish body damage rate during fishing. Due to the limitation of ROV size, small devices such as axial flow pumps are often used to provide pressure differences between the internal and external channels of the fishing system.

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Figure 2 Suction fishing ROV

3. Suction Fishing System

The suction fishing system can be divided into jet suction pump, centrifugal suction pump, submersible suction pump, and vacuum suction pump based on the structural principle of the suction pump.

3.1. Jet Suction Pump.

The high-speed water flow through the nozzle forms a negative pressure, collecting the mixture of caught organisms and water, and discharging it through a discharge pipe

Go out, the jet pump structure is shown in Figure 3. The jet suction pump has a simple structure and low cost. Due to the lack of impellers, it causes less damage to the caught organisms. However, it is prone to cavitation, difficult to process, and has a low energy conversion rate. It is usually only used in large aquaculture cages.

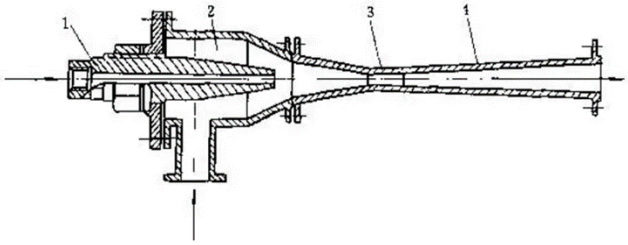

Figure 3 Construction of Jet Pump

1. Nozzles; 2- Inhalation chamber; 3- Mixing tube; 4-Diffusion tube

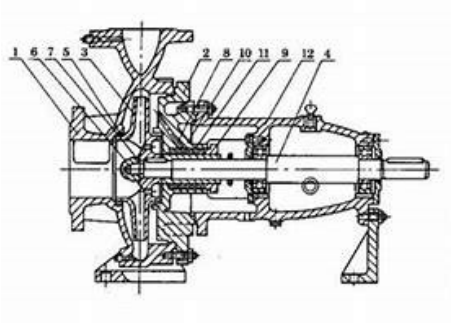

Figure 4 Schematic diagram of centrifugal pump

1. Pump body; 2- Pump cover; 3- Impeller; 4-axis; 5- Sealing ring; 6- Impeller nut; 7- Stop washer; 8-shaft sleeve;9- Packing gland; 10- Filler; 11- Suspension bearing components

3.2. Centrifugal Suction Pump.

By using hydraulic control to control the blades of the centrifugal pump, it achieves extremely high rotational speed, thereby generating negative pressure to be sucked away by the caught organisms. The principle of the centrifugal pump is shown in Figure 4. The energy conversion

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rate of the centrifugal suction pump is very high, and it can capture heavy organisms. However, the high-speed rotating blades can cause damage to the caught organisms, and the mortality rate of the caught organisms is extremely high. Centrifugal suction pumps are commonly used for loading and unloading in aquaculture cages and ocean going fishing boats.

3.3. Submersible Suction Pump.

Submerge the suction pump underwater and achieve the purpose of suction and capture through the principle of negative pressure. This pump has a simple structure, high efficiency, small space occupation, light weight, and easy operation. However, its head is not high and its cost is expensive, so it is usually used in fishing boats, transport ships, and base ships.

3.4. Vacuum Suction Pump.

Vacuum suction pumps are divided into two types: intermittent and continuous.

Intermittent vacuum suction pump: According to the amount of catch, each independent tank opens the intermittent working mode to cycle and complete the suction task. The pump has low working efficiency, high energy loss, and may cause varying degrees of damage to caught organisms. However, it is easy to operate, lightweight, and easy to transport and install. So this suction pump is mostly used in freshwater aquaculture ponds or industrial aquaculture ponds with short continuous working time and low fishing volume [7].

Continuous vacuum suction pump: Usually, two pump bodies are replaced to complete continuous and uninterrupted suction operations. Its efficiency is about 1.5 times higher than that of intermittent suction pumps, and its energy consumption is smaller. Due to the use of negative pressure principle, the damage to the caught organisms is relatively small, but its installation and transportation are difficult. Therefore, this type of suction pump is usually used in trawl and enclosure nets that require long-term operation and high fishing volume.

An open frame fishing robot using a water pump as the power source for the fishing system, as shown in Figure 5.

Figure 5 Open frame fishing robot

4. Structural Design

The overall goal of this design is to create a lightweight and modular sea cucumber fishing mechanism that can be carried with manned submersibles, underwater robots, and other vehicles. The overall layout of this design mainly includes a dynamic fishing system, a screening filter collection device, and a framework structure.

4.1. Fishing System.

Compared to robotic fishing systems, suction fishing systems have obvious advantages in fishing efficiency, sea cucumber damage, control difficulty, production cost, etc. However, pump suction fishing systems require a larger space, and if the design of the pump suction fishing scheme is not reasonable enough, it will still cause significant damage to sea cucumbers [8]. In

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summary, this article selects the pump suction fishing system as the basis for designing the fishing mechanism.

Based on the analysis of the principles and characteristics of four types of suction pumps in the previous suction fishing system, combined with the distribution of sea cucumbers in the seabed aquaculture area, this design intends to adopt a combination of jet and submersible pump suction schemes, and adopt a impeller free mode in the design to avoid damage to individual sea cucumbers.

4.2. Screening Filter Collection Device.

In the process of sea cucumber fishing, not all sea cucumbers can be caught, and they must meet certain specifications and sizes to meet the standards. The external mesh of the filter collection device is set to the minimum allowable diameter of sea cucumbers for fishing, and the internal mesh partitions of different diameters are set in the filter collection device to preliminarily screen the specifications of the caught sea cucumbers.

4.3. Framework Structure.

At present, underwater robots on the market generally adopt a frame structure [10], and one of the characteristics of frame type underwater vehicles is the anti-collision frame. When the control signal is out of control, water flow changes and other special situations occur, the anti-collision frame shows its importance in preventing damage to the internal components of the robot. The framework of this design is equipped with 8 thrusters, 4 of which are distributed in the vertical direction, ensuring the rapid and stable ascent and descent of the underwater robot; Four are distributed horizontally to adjust the posture of underwater robots, including forward, backward, and yaw. The front side is the control cabin, composed of circuit boards, control chips, batteries and other components, which is the "brain" of underwater vehicles; The rear side is the power source of the fishing system, and the front and rear compartments need to be balanced with weights. The middle part is the fishing system, including an expanding suction nozzle and a screening net frame, to achieve the fishing of sea cucumbers on the seabed [11]. Figure 6 shows the basic structure of an expandable graded suction and capture underwater robot.

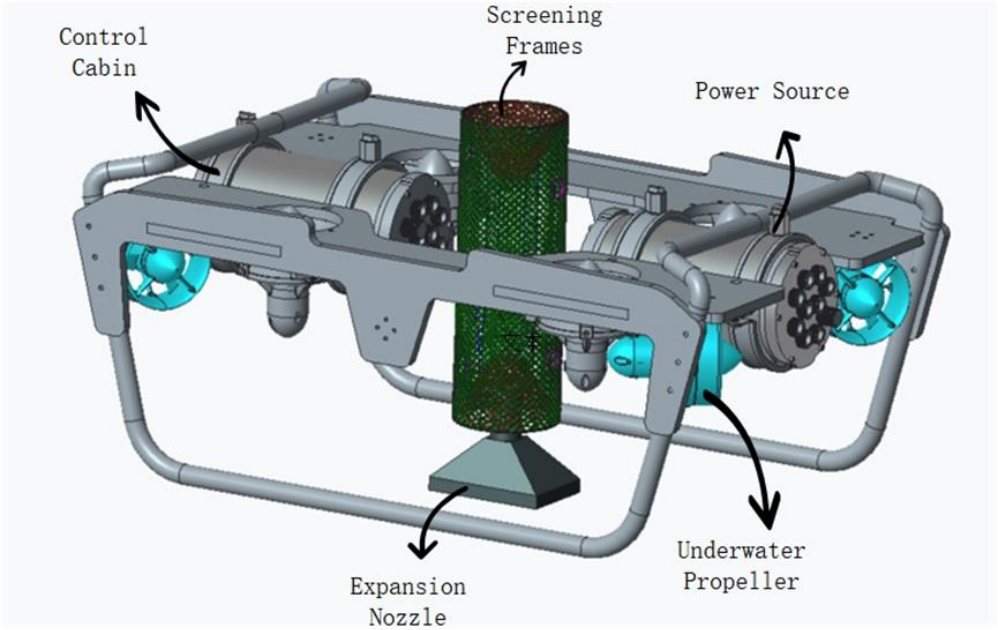

Figure 6 An expandable graded suction and capture underwater robot

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5. Framework Materials

Framework structure can be roughly divided into the use of metal materials such as steel pipes, aluminum alloy profiles, angle steels, and welding or bolts tight truss frame structure and plate frame structure reinforced with low-density plastic materials combined with local metal materials to enhance strength framework structure. The characteristics of metal truss structure are higher overall strength, smaller space occupied by the frame, and convenient disassembly installation and good maintainability; However, due to the extensive use of steel or aluminum, the overall weight of the machine has significantly increased, requiring more configurations. Due to the abundance of buoyancy materials, this form of frame structure is often used for medium to large-sized operational level underwater robots.

6. Conclusion

To solve the problems of low fishing efficiency and significant damage to the body of sea cucumber by the suction mechanism of sea cucumber fishing robots, this paper designs an expansion type graded suction mechanism for sea cucumber fishing operations. Its characteristics are: (1) The suction effect is relatively ideal, reducing damage to sea cucumbers. (2) Framework exterior design, low production cost, and short production cycle. (3) Good dynamic stability. The reasonable configuration of eight vector thrusters ensures that the robot can flexibly dive, float, operate conveniently, and be flexible. Based on the research and design analysis of this article, grasp the main aspects of the mechanical structure design of underwater robots, scientifically and reasonably optimize the design of shape, structure, size, materials, and layout, while paying attention to solving various problems that may be encountered in the actual work process, ensuring the implementation of underwater robot application functions and the improvement of performance.

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