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RESEARCH ARTICLE OPEN ACCESS

Research on a New Type of Deployable Cage Utilizing by Wave Energy for Deep-sea Culture

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ABSTRACT
With the high return of deep-sea fisheries and the cost reduction brought by cage technology development, the scale of deep-sea aquaculture is expanding rapidly. Cage culture has become a required strategic choice for the development of China's marine fisheries. In view of the huge volume of traditional cage, which is difficult to transport and the ineffective use of wave energy, and unable to adjust the water depth of cage according to the needs of aquaculture, a new type of deployable deep-sea cage with wave energy auxiliary supply is proposed. The cage is supported by a space deployable mechanism. Through the multi-point linkage drive of the moving pair, the outer frame of the cage is folded for the first time and then the overall frame is folded for the second time. Based on the collection of wave energy by float oscillation, an auxiliary energy supply device is designed to provide energy for the cage operation. The folding cage with wave energy auxiliary supply is proposed to provide a new idea for the development of deep-sea cage.
Keywords – deep-sea cage, deployable mechanism, the collection of wave energy

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I. INTRODUCTION

Deep-sea cage is the representative of advanced productivity of marine aquaculture, which is of great significance to expand aquaculture area, reduce environmental pressure, protect and regulate the structure of marine aquaculture species [1]. At present, the world's advanced rigid cage includes the hex box cage in Norway, the deep blue No.1 deep-sea fishing ground in China, the multi-functional ocean ranch platform in China, and the U.S deep-sea dish type anti wind and wave cage [2]. However, due to the huge volume of the traditional cage, which is not convenient for transportation, and the poor ability to resist wind and waves, the cage needs energy supply in the process of operation and the rich marine energy has not been effectively utilized, which limits its application in deep-sea aquaculture.

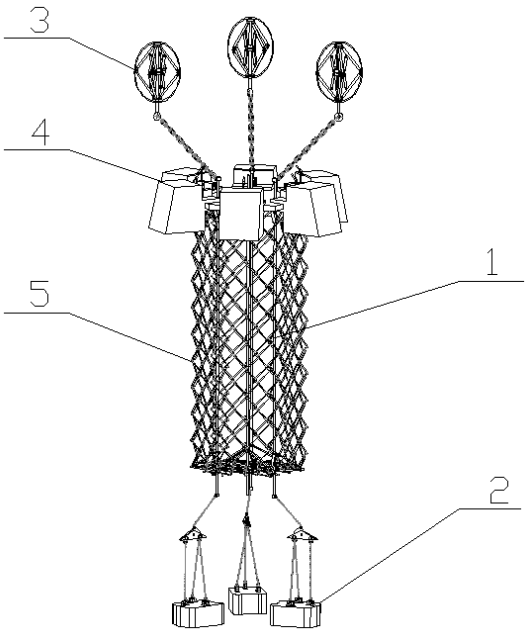
Space deployable mechanism has the function of repeatedly unfolding and folding [3]. It can not only be folded to a smaller envelope size for transportation, but also can be extended to a large structure in the working state. At present, it has been widely studied and applied in the field of aerospace and architecture. According to the needs of the development of space science and technology, NASA has successively developed and put into use a variety of space deployable mechanisms, such as the disk strut type extension arm [4], the Astro mast extension arm [5], and the ring column antenna [6]. Deployable mechanism has the advantages of small volume, convenient transportation, high reliability, and has broad application prospects and important research value in the cage design.

When the cage is working at sea, it needs lighting, catching and other work, which consumes a lot of energy. Because the cage is located in the deep-sea area, the energy supply is inconvenient, and the wave energy density in the area is large. If wave energy can be collected to supply energy for the cage, the endurance of the cage will be greatly improved.

In view of the above analysis, this article introduces the deployable mechanism and wave energy auxiliary supply into the design of deep-sea cage. A new type of deployable deep-sea cage with wave energy auxiliary energy supply is proposed. The components of the cage are introduced, and the folding and unfolding process of the cage is analyzed. The principle of wave energy collection by floatation oscillation is introduced, and the wave energy auxiliary energy supply device is designed.

II. THE OVERALL CONFIGURATION OF THE NEW FOLDING CAGE

In view of the problems of the existing deep-sea cages that are difficult to adapt to the environment, inherently large size, inconvenient transportation, and low stability, this article proposes a new type of double folding cage. The new double folding cage as shown in Fig.1 includes a cage body, wave energy generating devices, buoyancy devices and anchoring devices.

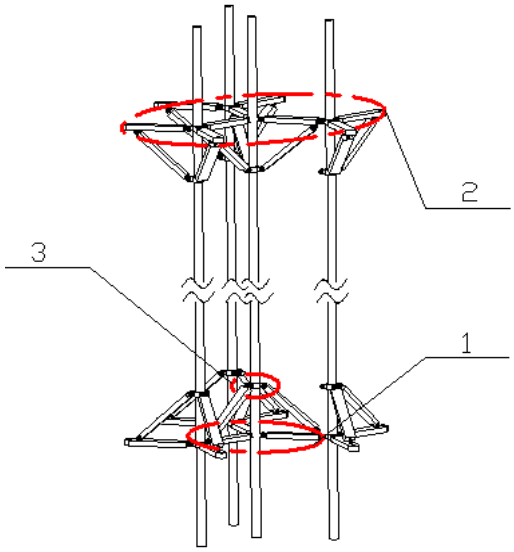


1-cage framework 2- anchoring device 3- buoyancy device 4-wave energy device 5-net clothing

Fig.1 a new type of deployable cage with wave energy auxiliary supply

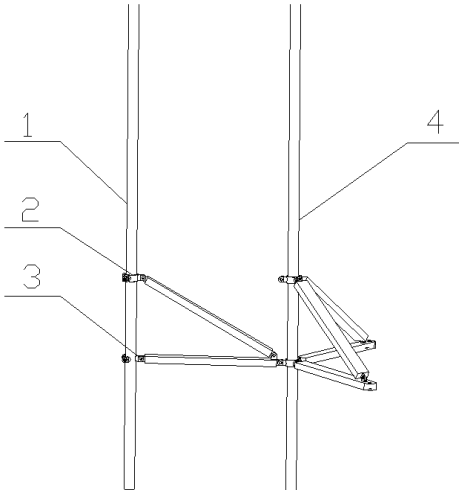
2.1 Double deployable cage frame

The double folding cage includes inner and outer frames, cage fold able mechanism and net clothes. The cage frame consists of the same frame on the top and bottom, and is also divided into internal and external areas, as shown in Fig.2. (The dotted circle in the Fig.2 is the connection point between the outer frame and the net clothing.) The cage frame is mostly composed of multiple units. A single unit is composed of a sleeve-type long shaft, a short connecting rod and a long connecting rod, As shown in Fig.3. The cage shrinks the entire envelope space of the outer frame to the outer circular long axis through the first folding, and then moves the surrounding long axis rod for the second folding to complete the inner frame contraction by the sliding movement of the central long axis. The schematic diagram of the mechanism is shown in Fig.4.



1-internal framework 2-external framework 3-deployable mechanism

Fig.2 net cage framework



1-central circular shaft 2-mobile pair 3-rotating pair 4-peripheral circular shaft

Fig.3 unit mechanism

A closed cage is formed by installing a net coat between the cage frames. The whole cage can be divided into internal and external parts, which can be contracted and expanded independently. The wave energy power generation device is installed in the top cage frame, which can store wave energy for lighting, catching and other aspects; the buoyancy device is connected with the top of the external frame to provide buoyancy for the cage; the anchoring device is connected with the bottom of the external frame, and the cage is fixed by the gravity of the anchor body.

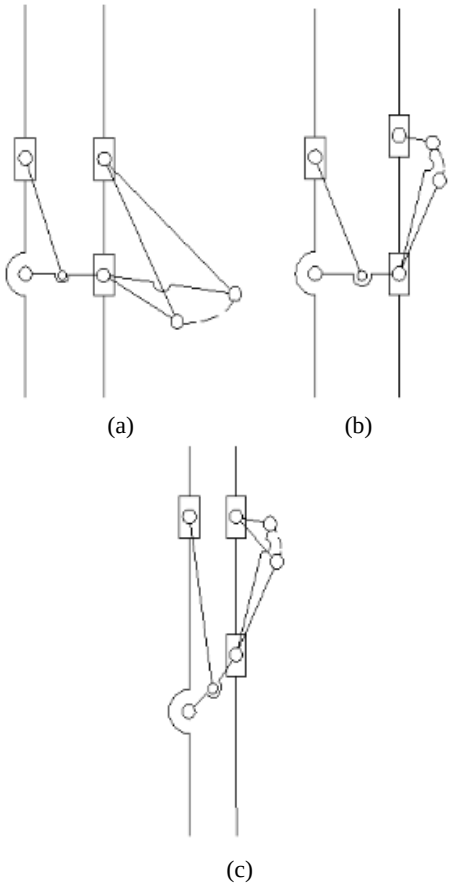


Fig.4 unit mechanism diagram: (a) mechanism diagram in fully expanded state; (b) mechanism diagram of the first fold; (c) fully closed mechanism diagram

2.2 Analysis of the folding state of the Double deployable cage

The coordinated movement of each part of the secondary folding cage ensures the stable development and retraction of the cage. The key status of the cage from expansion to collapse: full expansion, vertical expansion, primary folding and secondary folding (full fold). The cage frame expands to the plane state in the space, the sleeve type long axis expands up and down, pushes the lower frame to move down, and the cage expands longitudinally. The deployable mechanism of the cage installed in the frame mechanism drives the frame space to fold twice, and the cage is folded completely from the plane state to the parallel bundle state of each connecting rod. Then control the up and down expansion of the sleeve type long shaft to make the lower frame move up to complete the folding, As shown in Fig.5 .

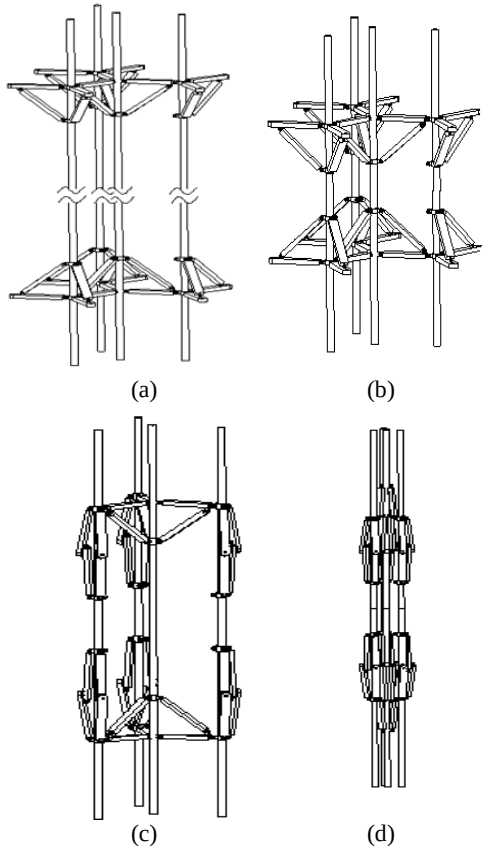
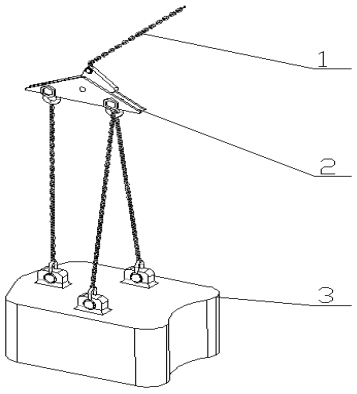


Fig.5 working state of cage fold: (a) fully expanded state; (b) vertical fold state; (c) first fold state; (d) full fold state

The new double deployable cage has the following characteristics:

(1)The cage structure is simple, light in weight, large in volume and capacity span. The cage frame is a rigid component, which can form a stable cage structure after being expanded. It can not only fold in plane, but also stretch and contract up and down. After being folded, it has a small envelope volume, which is convenient for transportation and catch of fish during the harvest period.

(2)The structural capacity of the double deployable cage is flexible and changeable. It can be folded once or twice according to the amount of fish or the demand of the environmental quantity density, so as to change the capacity and volume of the cage flexibly, which is conducive to the cultivation of fish.



1-steel chain 2-normal bearing bracket 3-the anchor
Fig. 6 anchoring device of deep-sea cage

2.3 Anchoring device

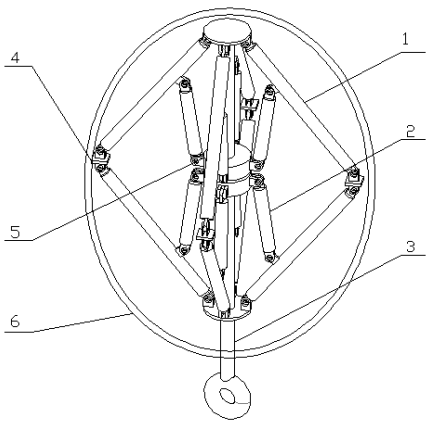
The anchoring device adopts ordinary bearing gravity anchor [7]. Compared with the traditional drag anchor or pure gravity anchor, the common load-bearing gravity anchor has the following outstanding advantages:

(1) High safety factor

Under normal circumstances, under the same load, the normal bearing gravity anchor is relatively stable, the direction of the normal bearing anchor is parallel to the normal direction outside the anchor plate plane, and the performance of the anchor is very similar to that of the normal plate (or block) buried in the soil, which is very suitable for the cable mooring system.

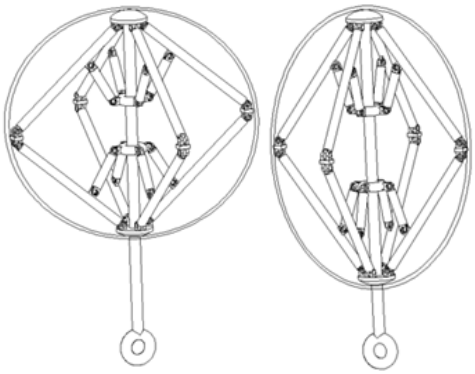
(2) High bearing capacity

Because of its multi-point bearing capacity and unique normal force characteristics, the bearing capacity is very high. It is preliminarily estimated that the normal bearing gravity anchor can bear 100 times of the gravity, and the ultimate tensile force of the anchor can reach 3.5 times of the installation load, which can safely solve the problem of cage fixation and bearing. The anchorage of deep-sea cage is shown in Fig.6.



1-supporting rob 2-driving rob 3-center vertical columns 4-connecting hinge 5-mobile pair 6-cover

Fig.7 buoyancy device



(a) (b)

(c)

Fig.8 the adjustment process of the buoyancy device: (a) fully expanded state; (b) folding state; (c) full fold state

2.4 Buoyancy device

The buoyancy device adopts the retractable umbrella mechanism. In order to adapt to the deployable cage, the buoyancy design is deployable and detachable. As a pendant, buoyancy can be provided by the hooks and air bags on the cage. The expansion state is shown in Fig.7, and the contraction state is shown in Fig. 8.

In order to realize the expansion of the mechanism, it is necessary to move the sliding pair up and down to the central cylinder. According to this characteristic, this project chooses to use the nut drive to make the sliding pair move. The nut is fixed and the screw is driven by the motor to drive the nut to move.

2.5 Net clothing

The whole net suitcase is mainly composed of net cover net clothes, net wall net clothes, net bottom net clothes and net clothes support made of flexible materials. The net clothing is easy to corrode when it is supported by rigid material. Therefore, flexible materials are used. Flexible ABS plastic is a kind of polymer material with large volume and wide application, which has excellent

mechanical properties such as toughness, hardness and phase balance. Therefore, flexible ABS plastic is used to make mesh. Flexible ABS has excellent mechanical properties, excellent impact strength and can be used at very low temperature. Flexible ABS is not affected by water, inorganic salt, alkali and various acids, as shown in Fig.9.

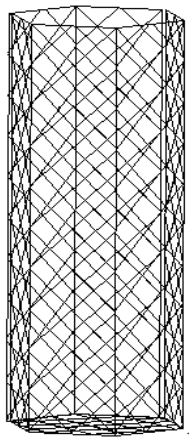


Fig.9 net clothing

III. DESIGN OF WAVE ENERGY AUXILIARY DEVICE FOR FOLDING CAGE

3.1 Power generation principle of wave energy auxiliary device

In view of the fact that the ocean is a huge energy treasure house, wave energy has the characteristics of high energy density and wide energy distribution. This paper presents a device that can absorb wave energy in cage culture. The device adopts a floating oscillating float hydraulic energy storage WEC power generation device. The oscillating float hydraulic wave energy device in the device is an energy utilization system integrating wave energy absorption, conversion and power generation. It is composed of multiple floats and multiple piston hydraulic cylinders to fully absorb wave energy within a certain area [8]. The oscillating floater wave power generation device is a system including three-level energy conversion device, in which the first level energy is converted to the oscillating floater system on the platform; the second level energy is converted to the hydraulic system; the third level energy conversion is the power generation system, which is similar to the conventional power generation system [9]. The power generation system is shown in Fig.10.

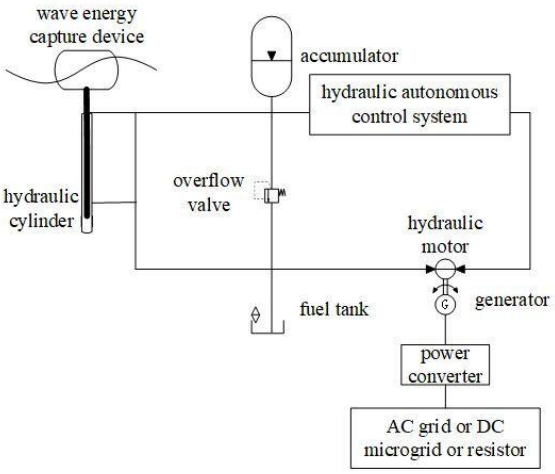
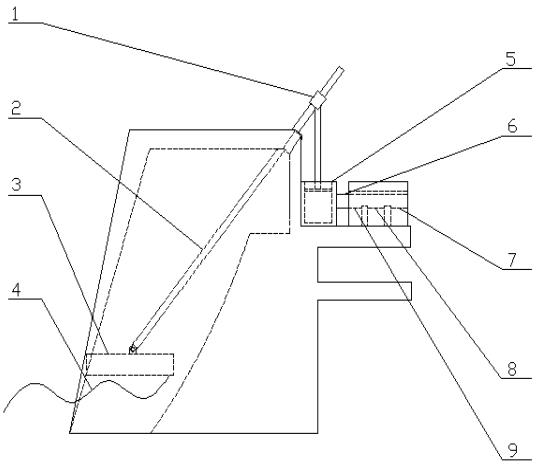


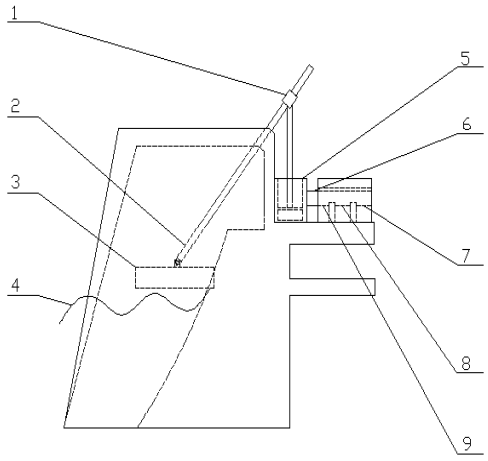
Fig.10 schematic diagram of hydraulic energy storing type WEC power system

3.1 Structural design of wave energy device

The wave power generation device designed in this article is divided into upper and lower layers: the upper platform is the main load-bearing layer, with most equipment installed, such as energy storage device, hydraulic motor, generator, unit control system, etc. The working environment of the platform is at sea. In order to prevent the important equipment on the platform from being affected by the strong storm and other external factors, the generator, energy storage device, hydraulic motor and other devices are specially placed on a stable platform. The lower platform is composed of a first-stage energy conversion system with floats and cavities, and a corresponding steel frame structure (mainly used for fixing float devices), as well as float arms and anti-typhoon equipment [10], as shown in Fig.11.



(a)



(b)

1-sleeve 2-float arm 3-float 4-wave 5-hydraulic cylinder 6-oil inlet and outlet pipeline 7-alternator 8-hydraulic motor 9-accumulator

Fig.11 working state of power generation device: (a) float status diagram at low water level; (b) Float status diagram at high water level

The undulating motion of the sea wave has rich kinetic energy and potential energy, which can transfer the energy to the float floating on the sea surface, and change into the kinetic energy and potential energy of the float undulating up and down. When the power generation device is working, the float is immersed in the sea water and fluctuates up and down with the wave. One end of the float arm is connected with the float, and the other end is connected with the hydraulic cylinder through the piston rod of the hydraulic cylinder. As shown in Fig. 11, the energy absorbed by the float from the wave is transferred to the piston rod of the hydraulic cylinder, and the wave energy is converted into the hydraulic energy, which is stored in the accumulator. Under the action of the wave, the hydraulic cylinder works continuously, and the accumulator pressure rises continuously. When the pressure rises to the upper limit value, the hydraulic autonomous control system starts the hydraulic motor, and the alternator generates electricity. At this time, the hydraulic energy is converted into electrical energy. The accumulator plays the role of storing the hydraulic energy converted from wave energy. After collecting a certain amount of energy, it can generate electricity in a centralized way, that is, to achieve the function of generating electricity by hydraulic energy storage.

3.2 Generation efficiency analysis of wave energy device

Matlab/Simulink is used to establish the power generation system simulation model [11], as shown in Fig.12.

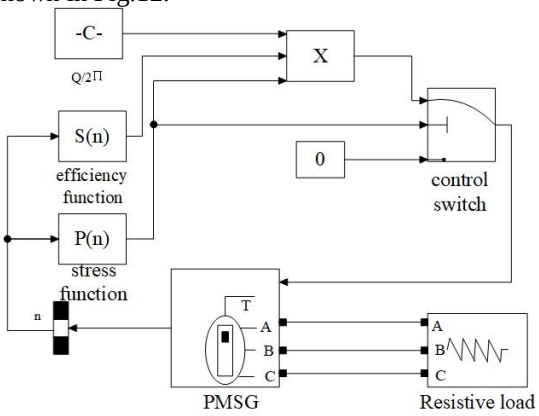


Fig.12 Generation system simulation model

The basic parameters are as follows: the accumulator capacity is 2mL, the starting pressure of the hydraulic motor is 20MPa, the stopping pressure is 9MPa, the flow rate is 60mL/r, the rated speed of the generator is 1500r/min, the output power is 3kW, and the voltage is 48V.Power generation can meet the requirements of lighting and feeding.

IV. CONCLUSION

The concepts of folding mechanism and wave energy absorption are introduced into the cage design, a new folding deep-sea aquaculture cage that can absorb wave energy is put forward, and a spatial fold able mechanism and wave energy absorption device are constructed. The folding process and structure of the cage are analyzed in detail.

Based on the increasingly mature oscillating float hydraulic energy storage WEC power generation device, a wave energy absorption device matching the deployable cage is constructed to effectively utilize clean Marine energy.

The new folding deep-sea aquaculture cage which can absorb wave energy has broadened the field of deep-sea aquaculture cage and has positive practical value.

ACKNOWLEDGEMENTS

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