# Array float bowls storm proof wave energy conversion system

used in island

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# Contents

Ab	stract		
1	Background4		
2 Designing Sch		ning Scheme	
	2.1	Overall Structure and	
	Ι	_ayout4	
	2.2	Work	
	I	Process	
	2.3	Structure of Each Part and	
	f	functions5	
	2.2	3.1 Float System	
	2.3	3.2 Transmission and Generating System	
	2.3	3.3 Auxiliary System7	
	2.3	3.4 Wave Generating System Model7	
3	Theore	etical Design Calculation	
	3.1 Re	elevant Parameters of Wave	
	3.2 Ca	alculation of Quality and Size of the Float	
	3.3 Ca	alculation of Damped of Torsional Spring9	
	3.4 Ca	alculation of the Float Absorb Potential Energy and Kinetic Energy9	
4	Worki	ng Principle and Performance Analysis10	
5	Innovation Points11		
6	Advantages11		
7	Refere	nces	

## Abstract

Ocean resources are rich around islands. A solution to the energy problem for islands is needed. Most existing energy systems using wave energy have many shortcomings like large space required, weak ability of wave/wind resistance, etc. They are not suitable for island. This work is a new array-type storm proof wave energy generation device which is designed as a medium-and-small-sized energy system for island. The equipment consisted of many floats and energy generation device. The vane is placed on the float. Between the float and the energy generation device is a transmission cable. When the wave rises from trough to peak, the float goes up and pulls up the cable; meanwhile, water dashes the vane and the vane furls the cable through the roller. It uses the rope to drive the generator. The rest energy used to reset keeps in the torsion spring which is in the end of the cable. When the wave travels from peak to trough, the energy saved in the torsion spring will retract the cable and wait for the next cycle. Contrary to existing wave energy equipment, this device has following features:

1)It breaks one single device into many smaller floats, which will improve the ability of wave/wind resistance and avoid the hogging.

2)Several cells work in different phase. They will complement each other and improve the generating quality.

3)It does not need land surface which will be more appropriate for island. And its modular structure will be more convenient for installation and maintenance.

Keyword: wave power generation float-type array-type distribution wave/wind resistance

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# **1 Background**

There is a vast ocean area and large amounts of ocean energy resources in our country, especially in the South China Sea. Clustered around the South China Sea are mostly islands. Compared with the ocean,land area of islands is so small that it is too difficult to produce electricity on the island. And because of the disputes in the South China Sea, China is speeding up its development in some islands. But those islands are far away from the land and is lack of energy supply. To achieve our country's sustainable development of those islands economically and militarily, we must adjust measures to local conditions. We should make the most of ocean energy and reduce our dependence on fueling<sup>[1]</sup>.

Using the ocean wave power is the main way of ocean wave energy utilization.It can provide clean power for outlying islands and offshore installations.The Oscillating Water Column (OWC) wave power device is more developed methods to use the wave power.But it is costly to build a dam.And it needs large land area unit power.<sup>[2]</sup>There are also nodding duck and Pelamis.These ways will suffer greater pressures when faced with the huge waves.Their device security is poor. In general, most existing energy devices are large single structures.They are complicated and poor in wave/wind resistance and have many other defects.<sup>[3]</sup>

This work is based on medium-and-small-sized independent energy system for island and puts forth a new low and medium power offshore wave energy generation. It absorbs potential energy through the the array floats. The impeller of the float absorbs the kinetic energy. And steel-rope drives the motor to generate. These ways are more advanced and feasible and can improve the shortcomings of existing devices.

#### **2 Designing Scheme**

#### 2.1 Overall Structure and Layout

Basic working of this work is absorbing potential energy through the array floats; the impeller of the float absorbs the kinetic energy and steel-rope drive the motor to generate. The basic structure of the device is shown in Figure 1.

The device is installed offshore from land 500~1000 metres. The caisson is installed on sea bottom and the floats float on the sea. The float is connected to the steel-rope and adjusts it. Based on the actual situation of the wave and the sea, it needs several floats. Each float has a corresponding caisson which can drive the generator through the transmission. Meanwhile, the vane furls the cable through the roller to drive the generator.



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# 2.2 Work Process

When the wave travels from trough to peak, the float goes up and pull up the cable; meanwhile, water dashes the vane and the vane furls the cable through the roller. It uses the rope to drive the generator. The rest energy used to reset keeps in the torsion spring which is in the end of the cable. When wave travels from peak to trough, the energy saved in the torsion spring will retract the cable and wait for the next cycle. The work process of the device is shown in Figure 2.



6

## 2.3 Structure of Each Part and functions

According to the above described overall structure and layout, we built a physical model as shown in Figure 3.And then we will introduce the structure of each part and function through the model.



FIG.3 Unit cell model structure chart

## 2.3.1 Float System

As is shown in figure 3, the float is a box structure. It can float on the water and will not sink under certain pulling force. The float is made by low density material or made hollow. The vane will be installed on the reverse side of the float and the side that faces the sea. When the wave comes, water dashes the vane and the vane furls the cable through the roller. And the float will roll up the cable with buoyancy either.

#### 2.3.2 Transmission and Generating System

Transmission and generating system include transmission ropes, adapting piece, pulley in the middle, transmission pulley, torsion reel and generator. Figure 4 is transmission and generating system.

Transmission rope is splited into two sections, and is made from different

materials. Rope 1 is linked to the float. Rope 2 is linked to torsion reel and two pulleys. These two ropes link up in adapting piece. Rope 1 is exposed directly to sea water. Its working environment is bad. So it is made from tensile corrosion resistant material. Rope 2 is placed in the box in the bottom as transmission rope. Choice of corresponding rope is based on the transmission pulley's type. Because rope 2 works in a good environment and need not to be long, good quality rope will do.

Adapting piece is a structure that connects two ropes and perfoms a sealing function. Rope and adapting piece do not move. When the rope is moving up and down, it contacts the outside box with the adapting piece. The outside surface of the adapting piece is glaze. Its airtightness is better than that of twisted steel wire rope .

The mid-pulley does not drive the load. It just adjusts the direction of the transmission rope. The transmission pulley's principal axis drives the electric generator. And there's a torsion spring in the torsion reel. When float rises, part of energy is kept in the torsion spring. And this part of energy will reset the rope when the float falls. The model uses the 3V direct-current generator to simulate electrical generator. And the LED simulates the load.



FIG.4 Bottom transmission structure chart

#### 2.3.3 Auxiliary System

As is shown in figure 3, the auxiliary system includes weights, intercepting pole, anchor, pull wire, etc. Constrained by the simulation wave system, the model is fastened in the bottom of water with weights. The intercepting pole and pull wire limit

the float's range of movement.



#### 2.3.4 Wave Generating System Model

FIG.5 Wave generating device structure chart

As is shown in figure 5, simulation wave generating system includes water tank and cart. The water tank is put on the cart. Push and pull the cart in small amplitude and certain frequency. The water in the tank has inertia. It will waggle and create wave.

# **3** Theoretical Design Calculation<sup>[9]</sup>

## 3.1 Relevant Parameters of Wave

Affected by the northeast monsoon, in winter, maximum of significant wave height moves toward southwestern of the South China Sea and it is above 3 meters. Significant wave height of most area reaches over 1.5 meters. In spring, high value bound of significant wave height moves toward northern of the South China Sea. The maximum reaches over 2 meters and most sea area reaches over 1 meter.<sup>[4]</sup>

Statistically, the average period of wave in the South China Sea is from 4 to 6 seconds. The significant wave height is almost 1.2 meters. <sup>[5]</sup>According to statistical data of significant wave height and average period, the general wave height is blow 5

meters and the average period changes within the range of 2s to 10s.<sup>[6]</sup>

According to the seasonal distributed data and distribution probability of the wave parameter, we use wave height as 1.2 meters and wave period as 4.5s to calculate.<sup>[7]</sup>

#### 3.2 Calculation of Quality and Size of the Float

Having taken into consideration the generated output and force status of the float, we take the float's length as 2m, width as 1.5m, height as 0.5m and the bottom is arc-shaped. Its volume is about  $1.2 \text{ m}^3$ , base area is  $3 \text{ m}^2$ .

The float's material is 2mm thick 304 corrosion resistant plate. Its density

$$\rho_0 = 7.93t / m^3$$

The under-boarding of the float is half of the base area. The weight of the impeller and roller is about a quarter of its shell. And the weight of the float is

$$M_1 = (1 + 1 + 0.5 + 0.25)\rho_0 LWd = 131 kg \approx 150 kg$$

#### 3.3 Calculation of Damped of Torsional Spring

The transmission cable between float and the box is 10mm stainless steel wire rope. Its length is 20m, effective length is 10m. When the rope elongates to 10m, the energy of the torsion spring is set as 3kJ.<sup>[8]</sup>

The energy of the torsion spring

$$E = \frac{k}{2} \cdot \alpha^2$$

Torque

$$M = k\alpha$$

Take the energy as 3kJ when it turn to 180°, then

$$k \approx 600N \cdot m / rad$$

Take the diameter of the wire drum as 0.5m(More than 10 times the diameter of the cable). And the force of the cable in original state is

$$F_{T} = k\alpha \frac{d}{2} = 600 \times \pi \times \frac{0.5}{2} = 471N$$

#### 3.4 Calculation of the Float Absorb Potential Energy and Kinetic Energy

Take the diameter of the vane wheel as 0.5m. Suppose around the vane wheel there is a hypothetical impression cylinder. Only spin the vane wheel with the water from the hypothetical impression cylinder. The flow velocity decline 30% through the vane. Having measured the wave horizontal velocity in different situations, we get an estimated value of absorbing kinetic energy in one cycle

$$E_p \approx 6 kJ$$

In the whole working process, there is pressure at the bottom of the wave to float. It push the float goes up. And there is no pressure on the top. The float absorbs potential energy from trough to peak:

$$E_k = \rho g \frac{H}{2} \cdot A \cdot H = 1000 \times 9.8 \times \frac{1.2}{2} \times 3 \times 1.2 = 21.2 kJ$$

3.5 Calculation of Generated Output and Energy Absorptivity

Absorption of kinetic energy and potential energy of float in one cycle have already been worked out above. According to wave period can get the generated output of one single float.

$$P_0 = \frac{E_p + E_k - E}{T} = \frac{6 + 21.2 - 3}{4.5} = 5.4 \text{kW}$$

The efficiency between transmission cable and the belt wheel is 0.9. The efficiency of the gearbox is 0.98. The efficiency of the flexible shaft transporting to generator is 0.9. And the power of one single float transporting to the generator shaft is :

$$P_{e} = P_{0} \times 0.9 \times 0.98 \times 0.9 = 4.3 \text{kW}$$

The wave length of the wave is about 50m. To ensure floats won't interfere with each other and have enough separation distance. Meanwhile, there is phase difference between each float. So set 5 floats in one line in one wave length. Each 10m set one line. Set 5 lines totally. So there are 25 floats on the 50\*50 scale. Based on the

relationship between the loss of long distance transmission and the distance, set 5 generator sets a regular pentagon in the center of this area. It constitutes a generator system.

This system 's total generator output

So choose 5 generator of 20kW.

According to statistical data, the average energy flux density of the South China Sea is 10kW/m<sup>2</sup>. So the absorptivity of energy is:

$$\eta = \frac{107.5}{10 \times 25 \times 3} \times 100\% = 14.3\%$$

#### **4** Working Principle and Performance Analysis

The basic working principle of the work is using the float to absorb the potential energy of wave and the vane wheel to absorb the kinetic energy.Energy transported to the bottom transmission mechanism through the transmission rope drives the electrical generator. Through ensuring that every moment has same amount of floats in different phase difference to drive the generator we ensure the efficiency of the generator and the stabilization of the generating quality. Multi-floats structural decreases the size of one single part, the hogging force of wave and strengthens the ability of wave/wind resistance.

According to the designing scheme, we made the physical model as shown in the figure 6. The test procedure is shown in the video. We simulate the load with LED. During the test procedure, LED illuminated by bright lights and the electricity generation performance is good. Under the circumstances of increased waves, the float also operated steadily. So the model's ability of wave/wind resistance is good.



FIG.6 Model physical chart

# **5** Innovation Points

- The device uses array type floats. It takes big energy absorption plant apart into several smaller one. The size of one single device is greatly decreased. Also decreased is the hogging force of the wave and strengthened is the ability of wave/wind resistance.
- 2) Several cells work in different phase. They will complement each other and improve the generating quality and stabilize the generator speed.
- It doesn't need land surface which will be more appropriate for island. And its modular structure will be more convenient for power expansion, installation and maintenance.

# 6 Advantages

Against background of applying medium-and-small-sized energy systems for island, compared to existing techniques of the same kind, this work has two major advantages:

In terms of stability, the existing devices costs a lot in manufacturing, installation and maintenance. And they are easy to be damaged, because their monomer structure is too big to bear large force. Their ability of wave/wind resistance is poor. And this work uses array-type floats. It is small for one single device and is good in resisting large wave and wind. Its modular structure will be more convenient for installation and maintenance.<sup>[10]</sup>

In terms of generating quality, most existing devices are large-scale monomer structure or several devices working at the same time. They are poor in generating quality. And this work has different floats working in different phases. They will complement each other to stabilize the generator speed and improve the generating quality.

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