Wave Absorptivity Analysis of a Nodule Type Wave Energy Device

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Abstract

With the socio-economic development, large-scale use of fossil fuels caused by energy problems and environmental problems become increasingly serious. Wave energy as a clean and renewable energy, has increasingly become the focus of attention. There are many kinds of wave energy devices in use. The nodule type wave energy device is an efficient wave energy conversion device.In this paper, according to the wave characteristics of Qingdao sea area, it describes the designing process of a nodule type wave energy device. The energy absorption rate of the captive energy device is calculated and analyzed in different wave periods. The wave energy absorption rate of the duck body is maximum when the ratio of the wavelength to the radius ratio of the duck body is 8, that the wave period is 3s.

Keywords

Wave energy, nodule type, the energy absorption rate.

1. Introduction

Energy is the material basis for the existence and development of human society. Over the past 200 years, the energy system based on fossil fuels such as coal, oil and natural gas has greatly promoted the development of human society. However, the serious consequences of large-scale use of fossil fuels are: the depletion of resources and the worsening of the environment. Therefore, the development and utilization of new energy has become a major research topic in today's society.

Wave energy is a renewable energy contained in the ocean. The wave energy is directly proportional to the square of the wave height, the motion period of the wave and the width of the wave front. Wave power generation can provide clean energy for remote islands and offshore facilities. Its development and utilization have matured and are entering or approaching the stage of commercialization [1].

The first application of wave energy can be traced back more than 200 years ago. The first invention patent of the wave energy conversion device was applied in Paris in 1799. Britain is the world's most abundant ocean energy country. In the early 1980s, Britain was already the center of world wave energy research. In the United Kingdom, the “Pela mis” wave energy plant with a capacity of 700 kW is a combination of stern and hydraulic systems and is the largest installed wave energy plant [2]. In the mid 1980s, Japan built two wave power stations with shore based fixed and breakwater, each installed at 40~125kW. In 1985, a wave power station with capacity of 500kW was built in Norway. It is the largest offshore wave power station in the world. The Wave Star Energy (WSE) Company in Denmark built an oscillatory buoy wave power station in 2006 with an installed capacity of 5.5kW [3].

The nodule type wave energy device consists of the duck body, the underwater floating body, the mooring system, the hydraulic conversion system and the distribution system. The wave energy of the nodule body is captured by the relative motion between the duck body and the underwater floating body, as shown in Fig. 1.The device was first designed by professor Stephen Salter of the university of Edinburgh in 1983, with an efficiency of 56%. Its main representative is Canada's WET EnGen nodule wave energy device [4].

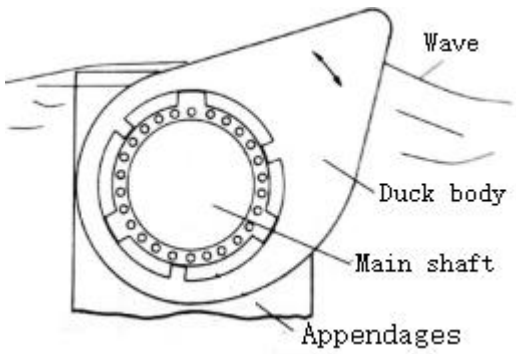

Fig 1. Nodule type wave energy device structure diagram

Qingdao is a coastal city with a sea area of about 12,200 square kilometers and a coastline of 816.98 kilometers (including its own shoreline). It has good wave energy resources. There are 69 islands in Qingdao [5]. It is very inconvenient to transmit electricity from the mainland to the island. Wave energy can be developed more conveniently than other forms of marine energy, providing considerable cheap energy through smaller devices. The main use of wave energy is to use it to generate electricity. The use of energy output from wave energy generators can provide power support for the extensive use of seawater, such as the production of hydrogen and the desalination of seawater. Wave energy generation can provide the clean energy for the island and the sea surface facilities far from the mainland. The nodule type wave energy generating device designed in this paper can provide continuous and clean electricity for islands, reduce the cost of transmission, and effectively solve the problem of island power supply.

2. Device Design and Working Principle

The energy conversion of nodule type wave energy generating device is divided into three levels: first-level conversion converts wave energy into swing-type mechanical energy, second-level conversion converts swing-type mechanical energy into hydraulic energy, and third-level conversion converts the hydraulic energy into the electric energy. Fig. 2 shows a wave energy conversion flow chart.

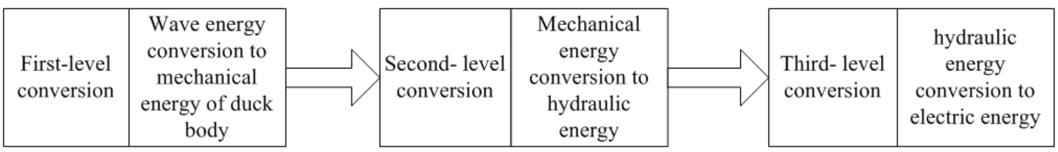

Fig 2. Wave energy conversion flow chart

The nodding duck wave energy generating device is composed of duck body, main shaft, hydraulic system, power generation system and appendages.

The duck body is the main energy capture device used to capture wave energy. The rotation of the duck body converts wave energy into swinging mechanical energy. The radius of the tail of the duck body is 1.75 m, the distance between the axis of the main shaft and the highest point of the duck body device is 4.13 m, the overall height of the duck energy-capturing device is 5.94 m, and the width of the duck body is 2 m. The duck body energy capture device is made of 316 stainless steel, which has good corrosion resistance and good toughness. The effect diagram of the duck body energy capture device is shown in Fig. 3.

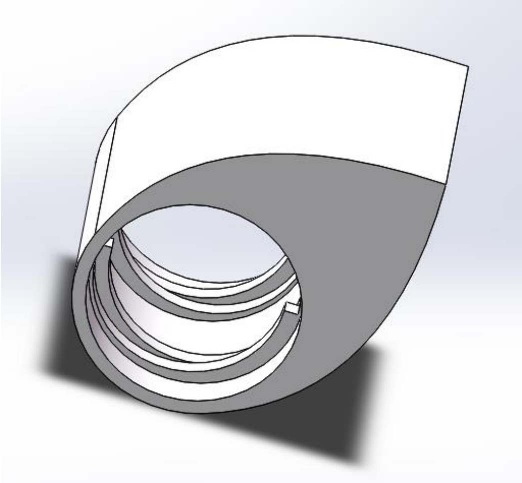

Fig 3. The duck body energy capture device

The main shaft of the nodding duck wave energy generating unit is the fixed support duck body capture device, which must have a certain stiffness and strength. This design uses 316 stainless steel as the metal material of the main shaft. The length of the designed main shaft is 2 m, and the outer diameter is 1.5m. The hydraulic column designed is placed inside the main shaft, and the hydraulic cylinder is opened on the main shaft, as shown in Fig. 4.

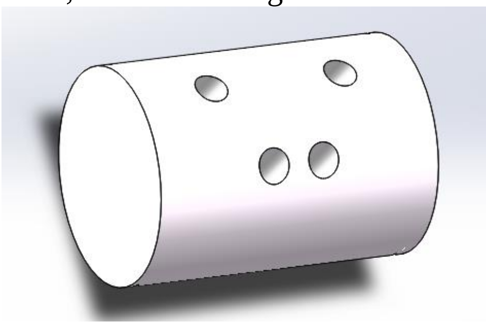

Fig 4. The main shaft

In order to restrict the movement of the main shaft of the nodding canard wave power generation device, underwater appendages is designed. The underwater appendages is designed with a rectangular steel plate with a bottom surface of 6m×6m, a thickness of 5 m, and an overall height of 5 m. As shown in Fig. 5.

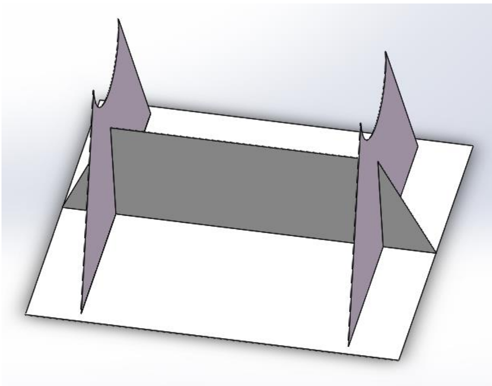

Fig 5. The underwater appendages

3. Theoretical Analysis

The energy absorption rate of the duck body energy capture device refers to the ratio of the total energy absorbed by the duck body to the total energy of the wave. The total energy absorbed by the duck body energy capture device is Ef, the total energy contained in the waves is E. The energy absorption rate of the duck body is:

$$\eta_f = \frac{E_f}{E} \tag{1}$$

As the horizontal wave force and vertical wave force of the duck body are known as the known periodic functions, it is necessary to study the absorption rate of the energy only in a wave period, and study the movement of the ducks in the horizontal direction and the vertical direction. The horizontal kinetic energy is EfH, and the vertical kinetic energy is Efv.

$$E_f = E_{fH} + E_{fv} \tag{2}$$

For linear waves, the total waves in a wave period can be written as [6]:

$$E = \frac{1}{8}\rho g H^2 \lambda B \tag{3}$$

The wave height of the wave model used in this paper is H=1m, the wavelength is λ=14m, and the wave width is B=2m (equal to the width of the duck body device).

4. The Experimental Analysis

According to the hydrodynamic analysis, the energy absorption rate of the duck energy-capturing device was analyzed under wave conditions with a wave height of 1 m and periods of T=2.5s, T=3s, and T=3.5s,T=4s respectively. The wave energy absorbed by the duck body energy capture device in different wave periods is shown in Fig .6.

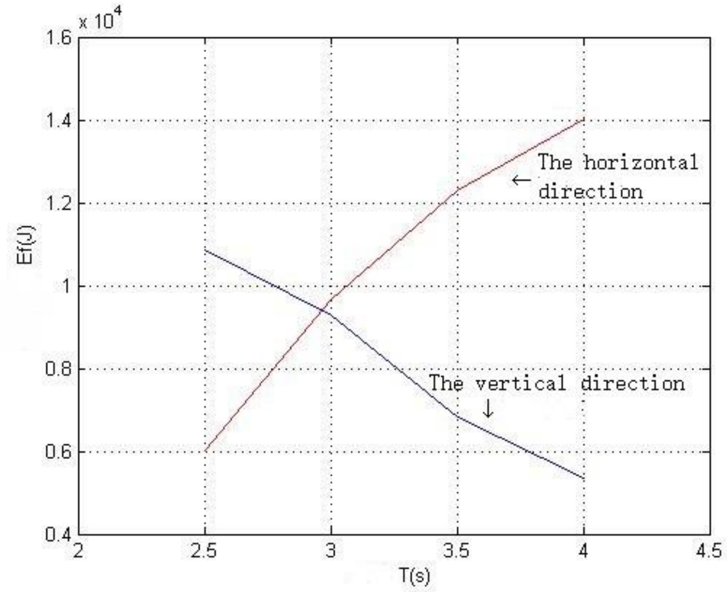

Fig 6. Different period duck body absorbs wave energy

It can be seen from Fig. 6 that the wave energy absorbed by the horizontal direction can be approximately proportional to the change of the period, and the wave energy absorbed in the vertical direction can be approximately inversely proportional to the periodic change.

This is due to the small relationship between the horizontal wave force and the wave period, but as the wave period increases, the horizontal wave force acts on the duck energy capture device for longer periods of time, so the wave energy absorbed by the energy capture device increases in a period.As the wave period increases, the vertical wave force of the duck energy harvesting device decreases. The large reduction of vertical wave force in a period still results in the decrease of the vertical wave absorption of the duck captive energy device.

From the curves of the wave energy absorption of different wave periodic waves in Fig. 7, it can be seen that the wave absorption rate of the trapping device is not linear with the wave cycle, and the wave energy absorption rate of the duck body capture device is the largest when the ratio of the wavelength to the radius of the duck body capture device is 8, that is, the wave period is T=3s.

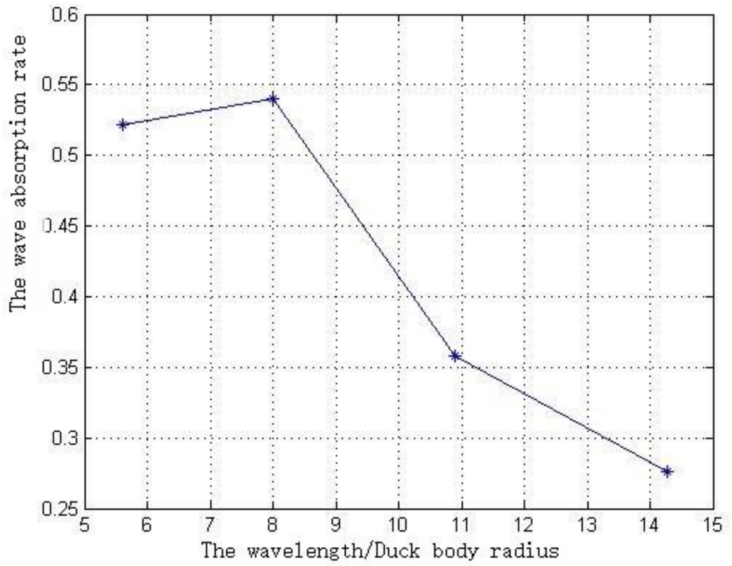

Fig. 7. Different period of wave energy absorption rate

With the increase of the wave cycle, the horizontal wave force and the vertical wave force are not coordinated, which causes the stability of the whole device to be reduced. At the same time, the power of the vertical wave force is less, and the wave energy can not be fully utilized because of the larger gravity of the power trapping device. When the wave period is less than 3, due to the larger vertical wave force of the device, most of the vertical wave energy is converted into useful work, and the total energy of the wave is relatively small. In this case, the wave absorption rate will be higher even if the wave cycle is short.

5. Conclusion

In different wave periods, the wave energy absorbed in the horizontal and vertical direction of the duck body has a linear relationship with the wave periodic variation. The wave energy absorbed by the horizontal direction is approximately proportional to the periodic variation. The wave energy absorbed by the vertical direction is inversely proportional to the periodic variation.

The absorption rate of the duck body is not linear with the wave cycle, and the wave energy absorption rate of the duck body is maximum when the ratio of the wavelength to the radius ratio of the duck body is 8, that the wave period is 3s. When the wave period is greater than 3s, the wave energy absorption rate of the duck's captive energy device decreases rapidly, and the wave absorption rate of the device is reduced to 27.6% at the time of 4s.

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