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Research on Efficiency of a Wave Energy Conversion System

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Abstract. The oceans are rich in wave energy that is green energy, and the wave energy are now being used to generate electricity on a massive scale. It can also be used as a single generator for beacon, buoy or underwater vehicle. Micro small wave energy power generation device is a kind of wave energy power generation devices, main characteristic is mobility is good, and can be directly assembled on various kinds of equipment for the power supply, with good prospects for development. . The research object of the paper is a new adaptive reversing wave energy generating device belongs to micro-sized wave energy generating device. Using the upper and lower absorber blade groups, the low speed and large torque wave energy can be converted into electric energy which can be used for load and lithium battery charging.

1. Introduction

The wave energy is caused by wind energy, and it is influenced by the geographical environment [1, 2]. Its energy change amplitude and frequency fluctuates greatly, which is an unstable and discontinuous energy form. To convert this energy into other forms of energy and convert to electrical energy for storage, a variety of energy conversion devices need to be designed and researched to maximize the ability of converting complex motion forms of waves into stable electrical energy that can be utilized and stored [3]. At present, the energy absorption conversion principle and structural form of wave energy generating devices are different [4]. For example, It can be divided into large-scale grid power generation, special equipment power supply and other direct energy supply by functional purposes [8]; According to the workplace and technology, it can be divided into shore-based, low efficiency and offshore type; According to its working principle, it can be divided into the over topping, the oscillating column and the oscillation float type; And according to the way of energy conversion type of back-end system, it can be classified into pneumatic, hydraulic and mechanical type [5, 6, 7]. The classifications like these can help researchers to understand the energy conversion ways of wave energy devices.

2. Model analysis

The absorption of wave energy is the source of wave energy generation systems. As the wave in reality is a random reciprocating oscillation, it is not conducive to direct absorption. The paper presents a kind of adaptive reversing wave energy generating device. As a new way of absorbing wave energy, it can convert the irregular motion of wave energy into a continuous rotary motion for generator, which reduced the complex transmission link, and can achieve high efficiency absorption and conversion of wave energy. In order to study the energy characteristics of the wave energy generating device, and to verify the feasibility of the method of stable charging, this paper designed a physical prototype, as shown in figure 1. The characteristics of the generator and the power generation and charging effect of the device are verified experimentally. The material used for blade is PE plate,

the blade ring is made of aluminum alloy, the connecting sleeve of blade and upper and lower absorber is carbon fiber, and the upper and lower absorber joint shaft is stainless steel.

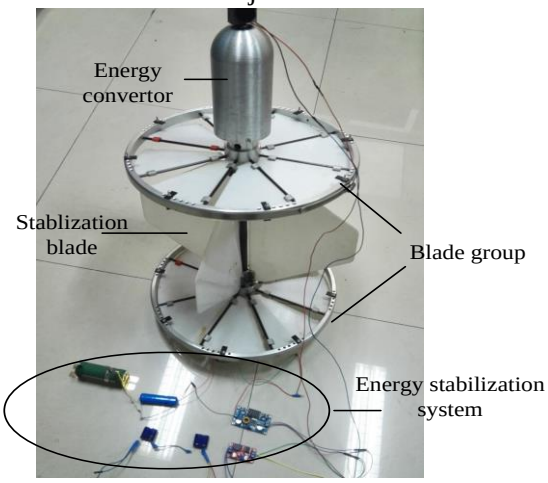


Figure 1. The structure of the prototype

Divide any blade on the device into small elements. Assume that, there is no interference between each element.

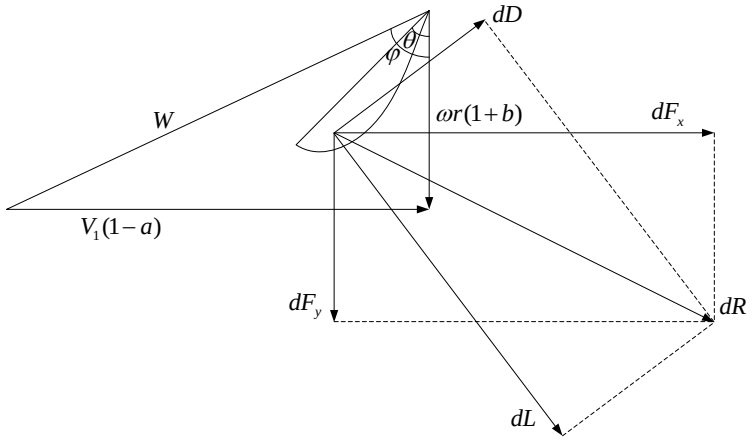


Figure 2. Force analysis of any element

α is the angle of attack, θ is the torsion angle of blade, φ is the angle relative to water velocity. Under axial induction and tangential induction, the water flow produced a relative water speed W, and the water flow also produced a hydraulic resultant force R. The resultant force R is decomposed into the vertical force (lift force L)and horizontal force(drag force D) relative to the water flow's direction. The expression of lift force element and drag force element is:

$$dL = \frac{1}{2}\rho W^2 C C_L dr$$
$$dD = \frac{1}{2}\rho W^2 C C_D dr \quad (1)$$

$$W = \frac{V}{\sin\varphi} \quad (2)$$

L is lift force, C is chord length, C_L is Lift coefficient, C_D is drag coefficient.

Decompose the lift force and drag force in the horizontal and vertical direction respectively, the horizontal and vertical resultant forces are calculated as:

$$dF_X = dL\cos\varphi + dD\sin\varphi = \frac{1}{2}\rho W^2 C dr C_X$$
$$dF_Y = dL\sin\varphi - dD\cos\varphi = \frac{1}{2}\rho W^2 C dr C_Y \quad (3)$$

Among them, $C_X = C_L \cos\varphi + C_D \sin\varphi$
$C_Y = C_L \sin\varphi - C_D \cos\varphi$

F_X is the axial thrust on blade, the thrust on the ring of the width dr at radius r is calculated as:

$$dT = NdF_X = \frac{1}{2}\rho W^2 NCdrC_X \tag{4}$$

And the torque is $dM = NdF_Y r = \frac{1}{2}\rho W^2 NCrdrC_Y$

N is the number of blades.
Combining the previous analysis, a and b is calculated as:

$$\frac{\alpha}{1-\alpha} = \frac{NCC_X}{8\pi r \sin^2\varphi} \tag{5}$$

$$\frac{b}{1-b} = \frac{NCC_Y}{4\pi r \sin 2\varphi} \tag{6}$$

If ignore the resistance generated by blade's shape.

$$\begin{aligned} C_X &\cong C_L \cos\varphi \\ C_Y &\cong C_L \sin\varphi \end{aligned} \tag{7}$$

So, $b(b+1)\lambda^2 = a(1-a)$

$\lambda = \frac{\omega r}{V_1}$ is the speed ratio at radius r

$$\tan\varphi = \frac{V_1(1-a)}{\omega r(1+b)} = \frac{1}{\lambda}\cdot\frac{1-a}{1+b} \tag{8}$$

$$\frac{BCC_L}{r} = \frac{8\pi a}{(1-a)}\frac{\sin^2\varphi}{\cos\varphi} \tag{9}$$

It can be see that, when absorber's basic design parameter determined, the flow angle is only relative to axial Interference coefficient a and tangential interference coefficient b.

3. Results and discussion

Build the experiment platform as shown in figure 3. The platform contains differential wave energy power generation device, linear heaving type electric cylinder, pool, Data Acquisition Card and PC etc.

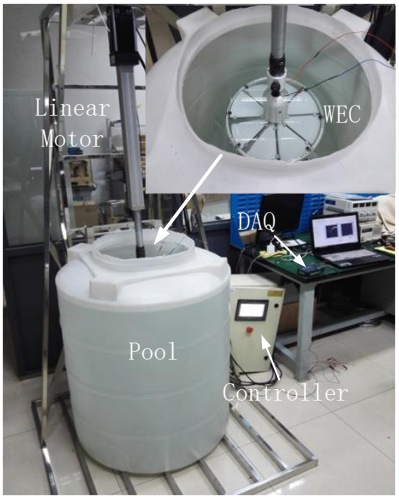
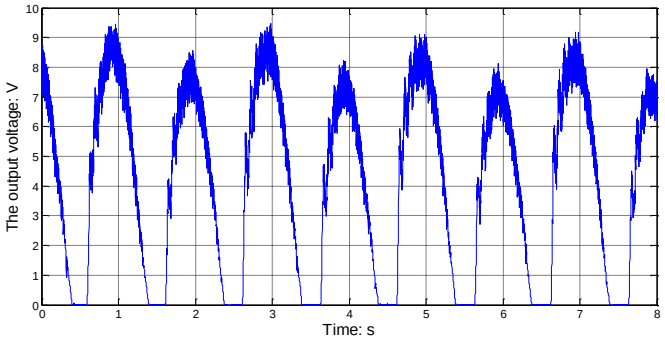


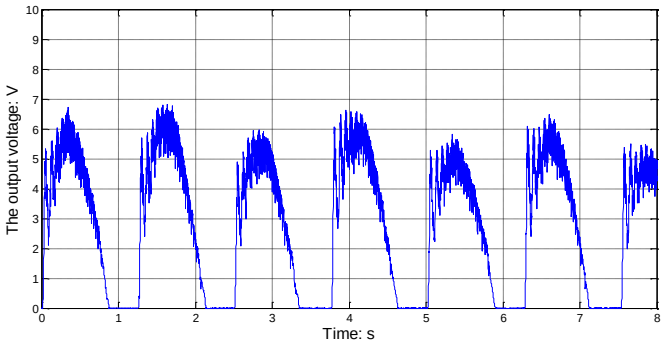
Figure 3. The platform for experiment

In consideration of the Amplitude and period of the absorber's motion are relate to the wave speed relative to device, so the second experiment verified the oscillating period's affection to the output voltage. Keeping the other parameters constant, and set the amplitude is 150mm, the electrical load is

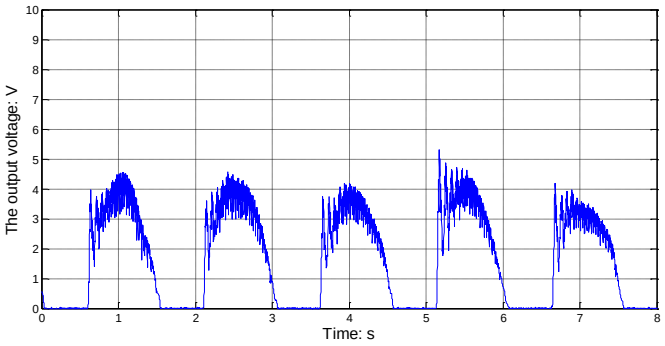
10Ω, and set the maximum blade angle is ±25°. Set the periodic variation in the range of 2~4s, the interval is 0.5s， the results are shown in figure 12.



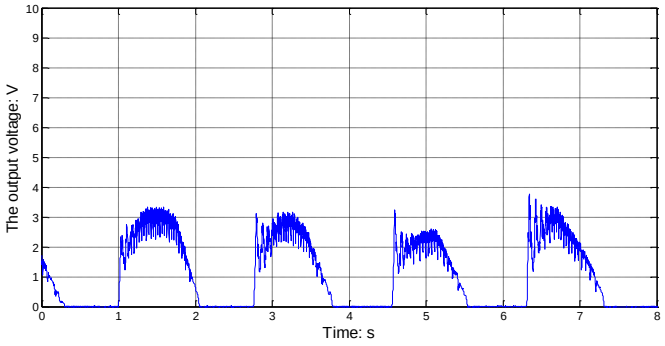
(a) The period is 2*s*



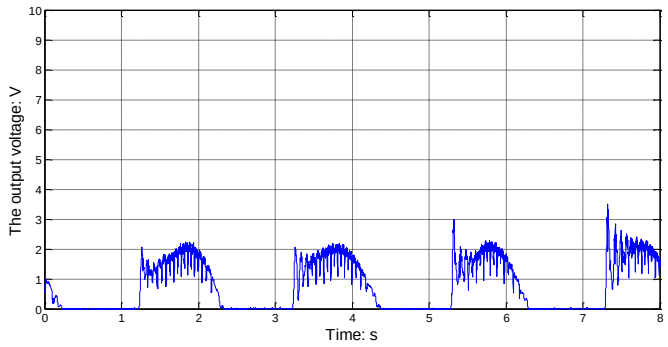
(b) The period is 2.5s



(c) The period is 3s



(d) The period is 3.5s



(e) The period is 4s

Figure 4. The output voltage corresponding to different period

From the results, it can be seen that, the longer the period, the more severe oscillation on the rising voltage waveform. It is because under the low speed, nonlinear generating voltage will increase the oscillation.

4. Conclusion

In this paper, a finite element analysis of the blades is carried out for the characteristics of the wave energy generating device, and the experimental platform is built and verified by experiments. According to the wave condition of 150mm wave height in different periods, the actual output voltage curve of the wave energy generating device is obtained. The periodic oscillation of the device causes the periodic oscillation of the output voltage. In one period of the device's movement, the output voltage varies by two periods. Between the device upward and the downward oscillation, there will be a time when the blades are not rotating, the output value on the voltage value is 0. This is also caused by the water resistance of the blade and the torque of the generator itself. To improve this situation, it can increase the speed of the wave relative to blade, or add quality to the outside wheel to increase the rotation inertia, and under the action of inertial force to ensure a sustainable blade rotation, and a continuous power generation process.

Acknowledgments

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