Experimental Research of a New Wave Energy Conversion Device

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Abstract. With the increasing tension of contemporary social energy, the development and utilization of renewable energy has become an important development direction. As an important part of renewable energy, wave energy has the characteristics of green environmental protection and abundant reserves, attracting more investment and research. For small marine equipment energy supply problem, this paper puts forward a micro wave energy conversion device as the basic of heaving motion of waves in the ocean. This paper designed a new type of power output device can solve the micro wave energy conversion problem.

1. Introduction

With the deepening of the marine exploration, functionality and performance of marine equipment put forward higher requirements[1, 2], such as detection of more powerful function, more intelligent control level, more reliable, more accurate navigation algorithm working state and longer working hours. However, these functions and performance can't be achieved without a premise: good battery life[3]. As an important part of marine energy, wave energy has the characteristics of large reserves, green environment and renewable energy. It is estimated that the annual amount of waves in the world's oceans can be in the range of 0.1 x 1010 to 1.010kW, with an average of 10~50kW per meter[4, 5]. If these renewable sources of energy absorption, transformation and storage, and provide energy for marine equipment, this will greatly improve the battery life and independent survival ability, realize long-endurance of offshore platform and a wide range of work[6]. This is of great significance to improve human's exploration and exploitation of marine resources and environment[7]. As the energy conversion method owns its pros and cons. To be specific, the pneumatic has high reliability but low conversion efficiency[8]; the hydrodynamic device has stable energy conversion efficiency, but the wave size will influence the absorbing performance; and the direct electrical device got the high conversion efficiency though, the complex mechanical transmission could be moderator variable[9].In this paper, a new type of micro-wave energy conversion device is studied by model description, analysis, and experimental research is also carried out.

2. Model Analysis

The energy absorber is mainly composed of rotating blade group, stabilizing wing, center shaft and blade baffle, as shown in figure 1. The blade group is mounted on the outer center wheel, and the upper and lower blade groups are connected through the central shaft. As the device moves up and down with the floating float, the water will impact the blades, as shown in figure 2. The upper and lower blades are installed in the opposite direction, when the impact is hitting, the upper and lower blade groups are subjected to the opposite lateral thrust. It generates a relative rotation and drives the connected generator to spin the electricity. The blade baffle is used to adjust the maximum angle of the blade group, so as to observe the effect of the angle of the blade on the absorption effect of the wave. Four stabilizer center symmetrically installed around the center shaft, the relative rotation with the upper and lower blade groups is also possible. When the device is in the water, the upper and lower blade relative rotating, the stabilizer remain relatively static in the water due to resistance function of the environment, so that can make the device not serious deviation, so as to improve the efficiency of energy conversion.

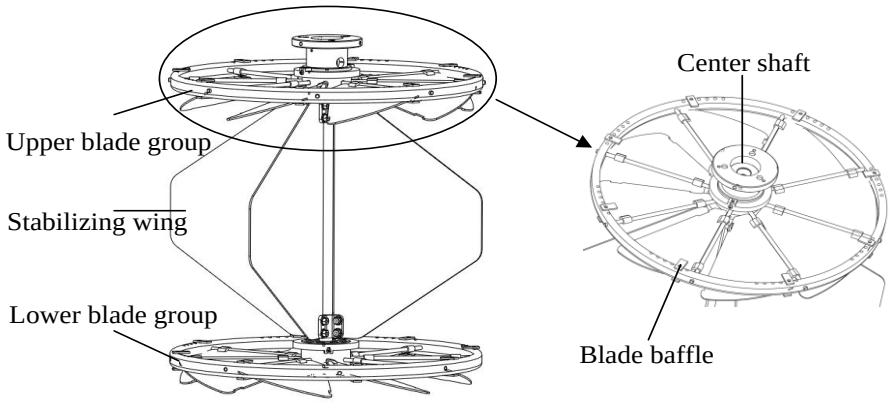


Figure 1. Structure of the wave energy convertor

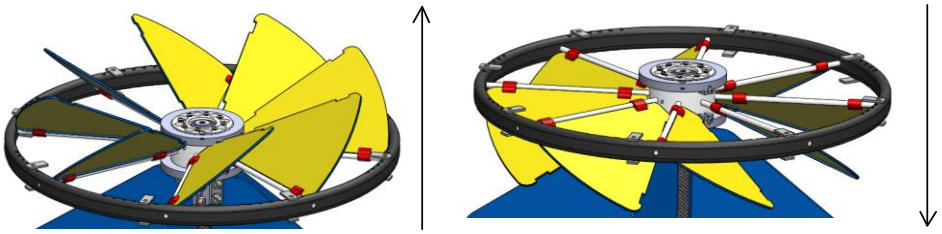


Figure 2. The impact of flow on blades

The model adopts the following assumptions: no friction, homogeneous, incompressible, steady state flow. And to calculate the maximum power of the device, assume wave-structure interaction of absorber (A) is equal to absorber (B), so the thrust on absorber (A) is also equal to absorber (B). Absorber (A) and absorber (B) have same design parameters. The parameters on absorber (A) are shown in figure 10, so the formula can be described as:

$$\begin{aligned} \omega_1 &= \omega_2 = \omega \\ J_1 &= J_2 = J \end{aligned} \tag{1}$$

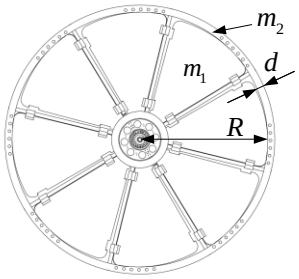
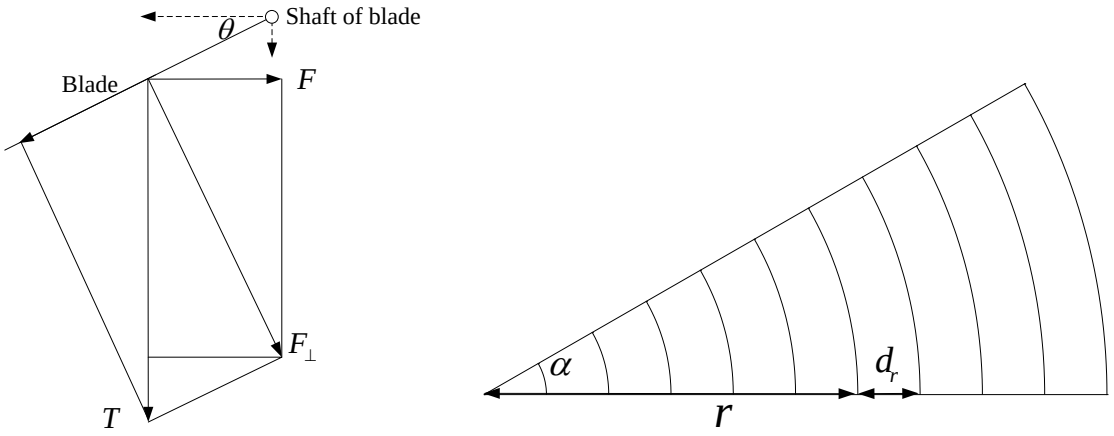


Figure 3. The parameters on one blade group

As shown in figure 11(a), T is the thrust on one blade, F is the thrust in circumferential direction.



(a) Force analysis from the side of any blade (b) Finite element analysis of any blade

Figure 4. Analysis of any blade

$$\begin{aligned} F_\perp &= T\cos\theta \\ F &= F_\perp \sin\theta \end{aligned} \tag{2}$$

Then the circumferential thrust on unit area is calculated as:

$$f = \frac{F}{\pi R^2 Z\cos\theta} \tag{3}$$

As the analysis shown in figure 11(b), the circumferential thrust on any blade is calculated as:

$$dT_F = \frac{F}{\pi R^2 Z\cos\theta}\alpha\cdot r dr \tag{4}$$

Then the circumferential torque is calculated as:

$$dM_1 = \frac{F}{\pi R^2 Z\cos\theta}\alpha g r^2 dr \tag{5}$$

$$M = \frac{F}{\pi R^2\cos\theta}\alpha\int_0^R r^2 dr = \frac{2\alpha R\cdot T\cdot\sin\theta}{3\pi} = 0.823N\cdot m \tag{6}$$

3. Results and Discussion

Analysis based on relevant hydraulic theory indicates that, dominant factors that influence efficiency of power generation include blade angle, shape and size.

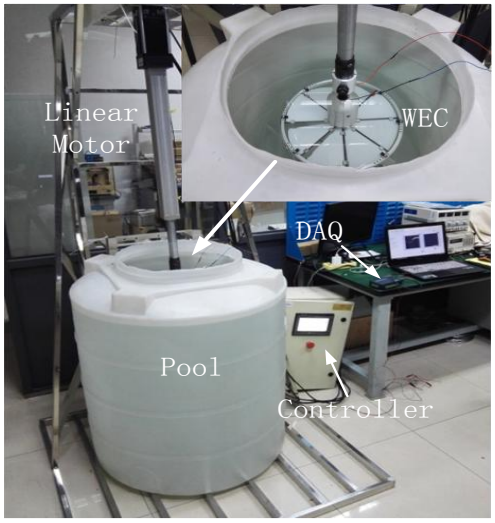
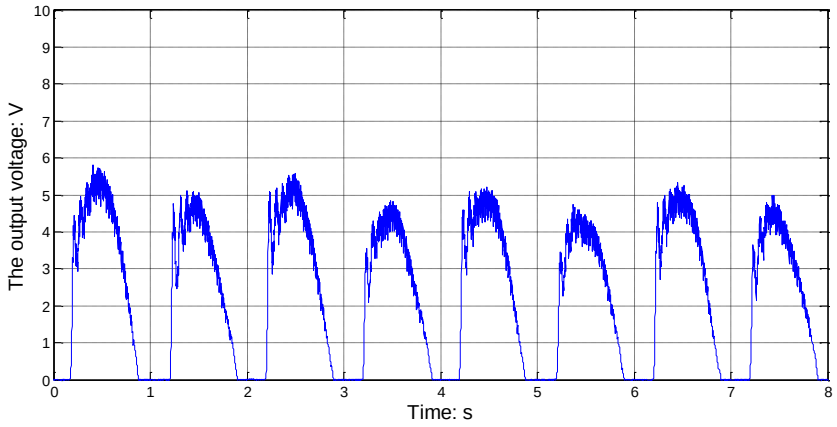
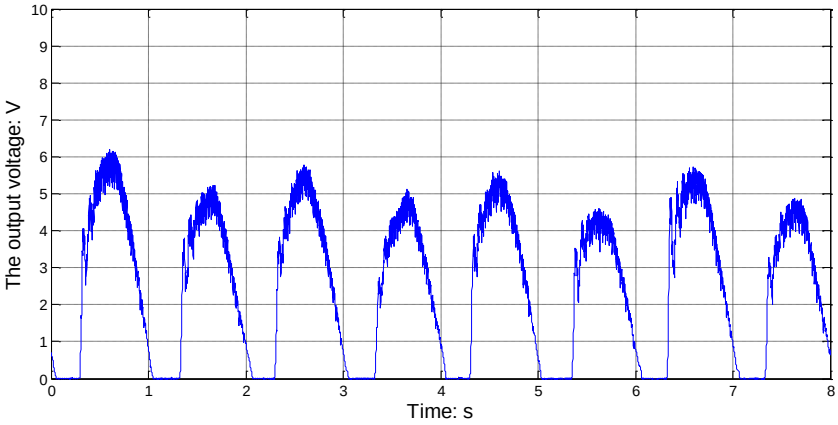


Figure 5. The structure of the platform

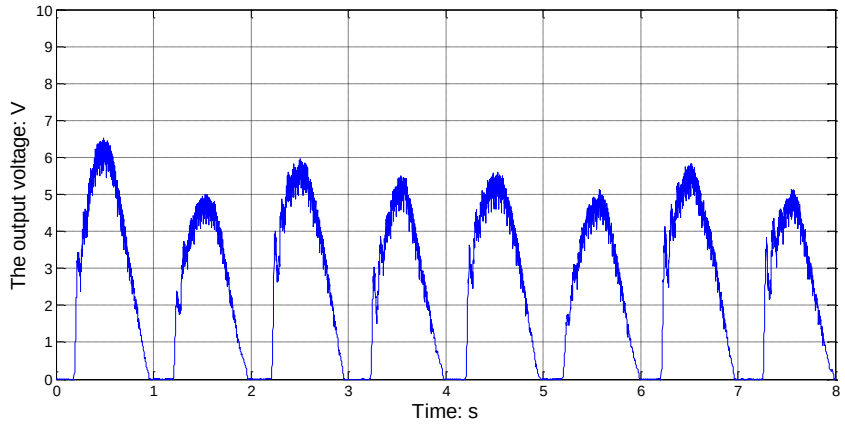
Build experiment platform under the laboratory environment as shown in figure 5. To verify the influence of maximum blade angle to output voltage value, set the amplitude is 150mm, the period is 2s, and set the electrical load is 10Ω. The test chose maximum blade angle (θ, as shown in figure) to be $\pm 25°$, $\pm 20°$, $\pm 15°$ and $\pm 10°$ respectively. The results are shown in figure 6.



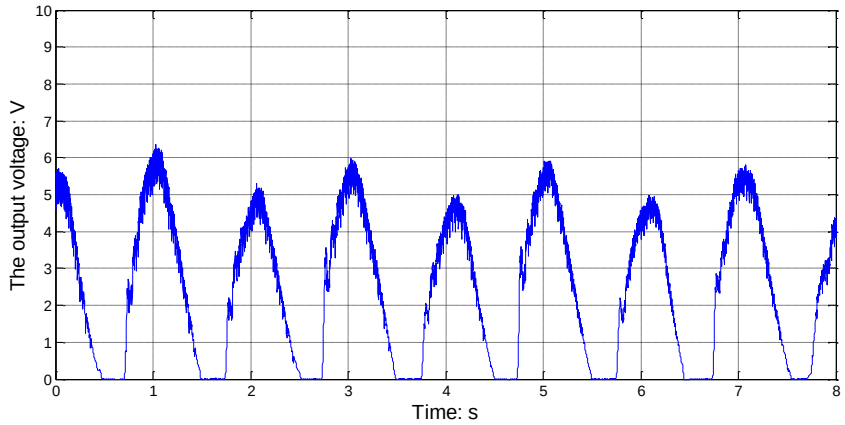
(a) The maximum blade angle is $\pm 25°$



(b) The maximum blade angle is $\pm 20°$



(c) The maximum blade angle is ±15°



(d) The maximum blade angle is ±10°

Figure 6. The output voltage corresponding to different the different maximum blade angle

It can be seen that, while the maximum blade angle is ±25°, ±20°, ±15° and ±10°, the maximum output voltage is about 5V, 5.5V, 5.7V and 5.9V respectively while the platform running stable. It also can be see that, as the maximum blade angle decreases, the output voltage increases, but when reduced to a certain value, the output voltage no longer increase. While the maximum blade angle is 0, the blade cannot rotate, so the absorber cannot obtain power. It is because that, while the maximum blade angle decrease, the circumferential component of thrust on the absorber will decrease, lead to the output voltage decrease. Even the circumferential torque cannot meet the starting torque of generator when the maximum blade angle decreases to 0. This experiment based on the experimental conditions described above indicates that, the output voltage will reach the maximum value when the maximum blade angle within the scope of ±15°~±10°.

4. Conclusion

A new kind of micro wave energy converter was designed in this paper. The innovation of the device is that it can converts wave energy into rotating mechanical energy, then into electrical energy. Based on the actual characteristics of power generation device and the power output of this wave power generation device, this paper builds experimental platform and verifies the experiment. The actual output characteristic curve and power generation efficiency of the generator are obtained, and the efficiency is less than 50%. Get the device output voltage under the different maximum blade angle.

When the blade angle is within the scope of $\pm 15° \sim \pm 10°$, the average output voltage is the largest, close to 6V. Future work such as simulation analysis and experiment in actual sea condition need to be done to carry on optimizing the design of the absorber mechanism, and to pick up the optimal parameters group more precisely and improve the energy conversion efficiency.

5. Acknowledgments

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