Influence of the PTO System on the Power of Wave Energy Generator

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Abstract. Nowadays the global demand for energy is growing rapidly, it is highly urgent to conduct the research and develop the efficient renewable wave energy equipment, wave energy converter (WEC). This paper introduces the PTO (Power Take-Off) system and theory of wave energy generators, which shows that the hydraulic system can transfer energy well. We found the relationship between the pendulum length and the wavelength of the floating pendulum wave energy generator and the relationship between the pendulum height and the wavelength. Through the influence of PTO on the power of different wave periods, the power increases first and then decreases with the increase of PTO and we also found the optimal PTO of different wave periods.

1. Introduction

As one important kind of new energy, wave energy is created by wind, and it is a by-product of the atmosphere’s re-distribution of solar radiation energy [1]. The advantage of wave energy is obvious and its development is sustainable because it combines key economic, environmental, ethical and social factors. The rich resources and high energy density of the ocean make the proper design of the equipment feasible and significant. The special advantages of wave energy also have limited environmental impact. The natural seasonal variation of wave energy follows the demand for electricity in temperate climates. For most forms of renewable energy, the development and utilization of wave energy means diversification of employment and the safety of energy supply in remote areas. In addition, large-scale implementation of wave energy technology will stimulate the development of manufacturing industries. Therefore, the study of wave power generation has a very good significance to improve China's environmental conditions and promote development [2]. If it is developed properly, it will become a national green energy technology.

The idea of transforming the energy of ocean surface waves into other useful energy patterns has been proposed for over two hundred years. The techniques were first patented as early as in 1799 [3], and, there were references to describe these techniques [4]. Leishman & Scobie had carefully documented the development of wave-powered devices from 1855 (the 1st British patent) to 1973 (when there were already 340 patents) [5]. Several configurations of wave energy converters had been designed and tested at model scale during the above period, and some of which had been in operation in the ocean.

The pendulum device uses the oscillating force to convert the wave energy into mechanical energy by the action of the wave force then converts the mechanical energy into electrical energy by mechanical or hydraulic.

Japanese researchers in the Department of Science and Technology first proposed the concept of hanging pendulum wave power plant in 1983 and a 5kW device was built in Lanzhou University of
Technology. Zhejiang University has studied the bottom-hinge buoyancy pendulum, which can be directionally drive the stroke during the whole oscillating process. There will be mechanical movements of the two hydraulic cylinders on both sides of the pendulum and the hydraulic system experiment of the model device was carried out in the laboratory.

Zhejiang University has also investigated the pendulum-type wave-type wave power generation device with shore-based adaptable tide changes [6,7]. This device can slide on a sloping coast. When the tide is descending, it slides down; when the tide rises, it slides up under the action of the buoyancy and wave force. A mechanical locking component could lock the device on the rail during the working time. The device has two wave collection components at the entrance of the wave, forming a bell-shaped mouth and the opening size of the wave device is adjustable to suit different wave conditions. The application of the wave device greatly increases the width of the wave front and increases the incident wave energy power. These merits reduce the cost and improve its economic value.

2. Mesh Generation

Date and Turnock [8] pointed out that the relative position of the fluid domain boundaries and devices was as important as selecting the correct boundary, as shown in Figure 1. The International Tow Pool Conference (ITTC) recommended that for simulations with incident waves, the entrance boundary should be located 1-2 LBP from the hull and the exit should be located at 3-5 LBP downstream to avoid any wave reflection from the boundary wall. In this paper, the calculation domain was set according to the wavelength. The device size was a variable and smaller than the wavelength and only a numerical water tank can be established. As shown in Figure 2, the inlet boundary was 1.5λ from the floating pendulum and the outlet was 2λ to the device. The area from 0 to 1.5λ from the outlet was set to wave-eliminating zone. The width of the device is small and the width of the sink is set to 0.5λ.

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Figure 1. 3-D view of the computational mesh and the applied boundary conditions
3. The computational domain and the hydraulic system

As shown in Figure 3, right end was the wave-making area, left end was the wave-cutting area, the wave energy generating device was fixed in the pool, and the device distance was 30m. The whole process was recorded by a camera, and the angle and displacement of the floating pendulum were recorded. The results were obtained by Post-processing.

As shown in Figure 4, the hydraulic energy conversion system mainly included a hydraulic pump, a check value, a regulating value, a hydraulic accumulator, a hydraulic motor and a generator. The hydraulic pump was connected to the floating pendulum and the hydraulic circuit. The rocker hydraulic pump delivered high-pressure hydraulic oil to the hydraulic circuit, as the floating pendulum swung upward and the mechanical energy of the floating pendulum was converted into hydraulic energy. The hydraulic pump did not work when the floating pendulum moving downward. The hydraulic pump drew low pressure oil into the hydraulic circuit so that it didn’t dampen during the downward movement of the floating pendulum.

Hydraulic accumulators were used to achieve a stable power output as the wave energy was random and unstable. If the accumulator was not installed, not only the hydraulic motor will be damaged but also the electricity will not be used directly. Therefore, the accumulator is designed in our system. Studies at the University of Lisbon in Portugal have shown that hydraulic systems with accumulators can transfer energy well with wave motion.
Figure 4: Hydraulic system

The hydraulic motor converted the energy of the high-pressure hydraulic oil into the mechanical energy. The hydraulic motor was connected to the generator through the coupling to finally convert the wave energy into electrical energy.

4. Results and discussion

PTO (power take-off) was the key to hydraulic equipment. Finding suitable PTO for different wave periods provided reference for the selection of hydraulic system. This chapter considered the distribution of wave periods and selected the wave period of 70% of the waves conditions in one year for T=5s, 6s, 7s while the wave height H=1m was selected at the same time. This study had practical significance. We found the optimization scheme of PTO damping coefficient under different wave period conditions. As shown in Figure 5, the optimal choices of the PTO damping coefficient were 5000000, 4500000 and 5500000. In these cases, the output power of the device is 48.32KW, 64.21KW, 63.33KW. We calculate the energy at the peak and found the efficiency 66.2%, 59.8% and 42.7% respectively.

Figure 5: Optimal linear torque power curve
5. Conclusion
This paper introduces the principle of the hydraulic system of the floating pendulum wave energy generator. It has been found that the hydraulic device is indispensable for the whole wave energy generation process. The results show that within a certain range, the increase of PTO damping coefficient will lead to the decrease of the efficiency of power generation. The hydrodynamic performance of a 1:10 scale model of a nearshore floating pendulum wave energy device was investigated and we have obtained multiple sets of data to reduce the power generation with the increase of PTO damping coefficient from simulations. The best linear torque power under different wave periods was obtained.

6. References
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