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Review on Wave Energy Technologies and Power Equipment for Tropical Reefs

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***Abstract*— As a promising renewable resource to replace part of the energy supply, the wave energy is having more and more interest worldwide. This paper presents a comprehensive analysis of different wave energy technologies in order to identify more promising methods for power supply to tropical reefs. It starts with summarizing the characteristics of tropical reefs in which the most suitable places to be exploited are showed, and the classification of different types of wave energy converters according to their construction features. It is also described in detail each of the stages that are part in the energy conversion. On the basis of the characteristics of tropical coral reefs the paper puts forward a new type of raft wave energy device which can achieve high operational reliability and adaptability with cost-effective deployment.**

Keywords—renewable energy*; *wave energy harvesting*; *tropical reefs

I. INTRODUCTION

A. The wave energy resource

The main disadvantage of wave power, as with the wind from which is originates, is its (largely random) variability in several time-scales: from wave to wave, with sea state, and from month to month (although patterns of seasonal variation can be recognized).

The assessment of the wave energy resource is a basic prerequisite for the strategic planning of its utilization and for the design of wave energy devices. The characterization of the wave climate had been done before for other purposes, namely navigation, and harbour, coastal and offshore engineering (where wave energy is regarded as a nuisance), for which, however, the required information does not coincide with what is needed in wave energy utilization planning and design.

The studies aiming at the characterization of the wave energy resource, having in view its utilization, started naturally in those countries where the wave energy technology was developed first. In Europe, this was notably the case of the United Kingdom [1,2]. When the European Commission decided, in 1991, to start a series of two-year (1992—1993) Preliminary Actions in Wave Energy R and D, a project was included to review the background on wave theory required for the exploitation of the resource and to produce recommendations for its characterization [3]. The WERATLAS, a European Wave Energy Atlas, also funded by the European Commission, was the follow-up of those recommendations. It used high-quality results from numerical wind-wave modeling, validated by wave measurements where available and contains detailed wave-climate and wave-energy statistics at 85 points off the Atlantic and Mediterranean coasts of Europe [4]. The WERATLAS remains the basic tool for wave energy planning in Europe.

These data concern locations in the open sea, at distances from the coast of a few hundred km. As the waves propagate into the shore, they are modified in a complex way by bottom effects (refraction, diffraction, bottom friction and wave breaking) and by sheltering due to the presence of land (namely headlands and islands). For these reasons, the wave energy resource character-utilization in shallower waters (say less than 50 m water depth) has been done only for specific sites where plants are planned to be deployed.

B. The tropical ocean reefs situation

The power demand supply of tropical ocean reefs is huge, and the prominent contradiction between supply and demand is increasing.

The power energy demand of the construction and development of tropical reefs mainly includes power supply equipment, lighting at night, staff living electricity, engineering equipment demand, and so on. At present, the power supply on tropical ocean reefs depends heavily on diesel generator, which not only hinders people’s daily life on the islands, but also procrastinates development of reefs. To make it even worse, the operation cost is high, so that diesel supply is hard to maintain. In practice, there is also maintenance issues, including:

(1) Due to "three high" (high temperature, high salt, high humidity) climate on tropical ocean island, plant unit has trip or shutdown fault issues a lot, which requires hiring professionals and bringing them to the island to conduct maintenance, parts

replacement, perform seasonal maintenance etc.

(2) Diesel supply line of diesel generator is prone to rust due to tropical climate, and the diesel pressure is so high that the pipeline leakage occurs easily.

(3) The tropical ocean reef is generally far away from the mainland. Therefore, diesel can only be transported by vessel, and the supply is limited every load. The transportation greatly depends on sea conditions, and it is normal that supply cannot be met due to the poor sea condition.

Aimed at the characterization of the wave energy resource, having in view its utilization, the studies started naturally in those countries where the wave energy technology was developed first. In Europe, it was notably the case of the United Kingdom [5]-[6].With the demand for tropical ocean reef construction growing high, electricity demand and electricity shortage will be greater.

Vibration Energy Harvesting (VEH) is a new energy technology. Its main principle is to transform vibration energy into electrical energy using MEMS technologies. VEH has compact structure, recycling a clean source, and has strong ability to resist external interference.

This paper summarizes the technical characteristics of various ocean wave energy generation devices, analyzes the realistic condition of the tropical island of wave power, and makes a new suggestion for the tropical island power supply, which can be an effective supplement of the existing energy supply modes as it has more economic value and wider development prospects.

II. CONDITION OF TROPICAL OCEAN REEFS POWER SOURCES

Power supply plays a major role in marine construction and development. Through investigation and analysis, the current tropical ocean reefs power sources mainly include five forms: diesel power generation, solar power generation, wind power generation, tidal power generation and wave energy generation.

A. Diesel generator

At present, diesel power generation is widely used for the power source, it has the advantages of mature technology, simple structure, small space occupation, simple operation, high reliability as well as convenient maintenance, and could meet the requirements of miniaturization and convenience of the tropical reef. But there are still some problems, the continuous supply to diesel fuel, long security distance and cycle, often affected by bad weather conditions such as typhoon, difficult security, high transport costs, cannot achieve self-sufficiency requirements and high dependence on the outside.

B. Solar power

Solar power is to achieve the electronic characteristics of P-V conversion by semiconductor materials, directly convert the solar energy into electricity. The advantage of solar power generation is wide resources range, convenient to access, stable energy, green renewable. However, the main problems include low photoelectric conversion efficiency, small energy distribution density (only about 100W/m^2); solar energy is not continuous power generation, the annual power generation time is a bit low, affected by the weather conditions such as season, illumination and so on, the cost of photovoltaic system is high, about 40000-60000 yuan /kW, and long-term exposure to the air, the durability equipment is poor due to vulnerable to environmental corrosion.

C. Wind power generation

Wind power generation is the use of wind power to drive the windmill blade rotation, and then through the growth rate of the machine to speed up the rotation, drive the generator to generate electricity, to achieve the conversion of wind energy into electricity. The advantage of wind power generation is that the resources are rich and renewable, and the structure is relatively closed. However, the main problems include the high cost of wind power generation, the stability of power generation and the price performance cannot be achieved at the same time, the volume is large, occupy a lot of space, vulnerable to severe weather such as typhoon damage.

D. Tidal power generation

Tidal power is to use two times a day and month due to the rise and fall of the water level and water flow interaction of the moon the sun's gravity tide generated by the difference caused by the change of the energy conversion. The advantage of tidal power generation is the high energy density, green renewable. But the main problems include the high requirements of the geographical position, generally choose the prominent headland or Strait; turbine long immersion in seawater, the seawater corrosion effect is stronger, more demanding on the unit material selection; infrastructure one-time investment is larger, larger area.

E. Wave power generation

Wave power is periodic motion caused by wind blowing by sea level changes and atmospheric pressure water rules, through the wave energy conversion of wave energy into motion of reciprocating machinery, through the dynamic uptake system is converted into electrical energy. The advantage of wave energy generation is that the energy density is high, the stability is good, the green renewable. The main problem is that the technology is more difficult, and it needs to break through the core technology of energy conversion. The device is also immersed in seawater for a long time, which is strongly influenced by seawater corrosion.

Based on the above analysis, table 1 gives the main sources of marine power and their respective characteristics.

Table 1 Comparison of main sources and characteristics of tropical ocean reef-power.

Power source type	main features					
	Power generation	Construction area	Mobility	Construction cost	maintenance cost	supply difficulty
Diesel generator	Low	Small	Yes	Low	High	High
Solar cell power generation	Middle	Middle	No	High	Low	Low
Wind turbine generator	Middle	Middle	No	High	Low	Low

Turbine generator	High	Big	No	High	Low	High
VEH generation	Low	Small	Yes	Low	Low	Low

The research is based on the unique climate condition (high salt and high temperature and high humidity) and geographic condition (away from inland, independent location, small area) of tropical marine reefs, where solar power, wind power, and tidal power are fatally limited. Compared with other forms of renewable energy, wave power generation has its technical advantages. Its high energy density, high degree of utilization, clean and renewable source, compact structure, small footprint, and mobility helps meet specific needs. Therefore, wave power generation will be the main research direction in marine utilization and development in the future. It will also play a key role in the development of marine resources and national defense science and technology.

III. RESEARCH STATUS OF VEH POWER GENERATION MECHANISM

The principle of VEH power generation is that the mechanical energy can be converted to the reciprocating motion of hydraulic cylinder, which can then be converted into a one-way rotary motion of the hydraulic motor, thereby generating electricity by a DC generator. The flow chart of the generation mechanism is shown in figure 1.

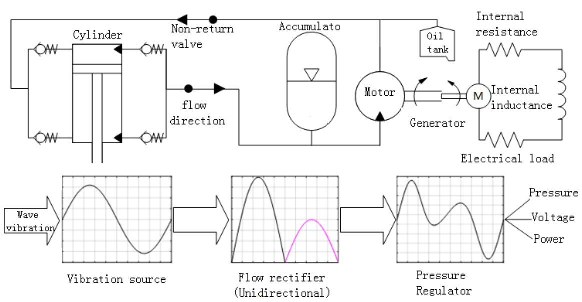


Fig. 1. Schematic diagram of VEH power generation

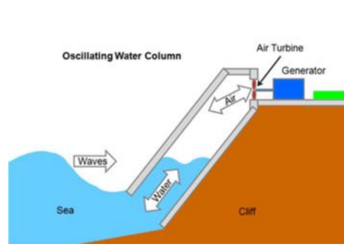
IV. VEH STRUCTURE DESIGN AND RESEARCH STATUS QUO OF TYPICAL DEVICES

VEH structure mainly includes six types: Oscillating water column (OWC), Tilting, Raft, Canard, Oscillation float structure and Overtopping converters.

A. *Oscillating Water Column (OWC) structure*

OWC structure uses air as medium. Under the impact of wave force, OWC forces air in the upper chamber to move. As air reciprocates through the air outlet at the top right of the chamber, wave energy is converted to pressure energy and kinetic energy of the air. Installing an air turbine at the nozzle and linking the turbine shaft and the generator will compress air to drive the turbine to rotate and drive the generator to generate electricity. It works as shown in figure 2[7]-[8]. Shoreline OWC prototypes (also equipped with Wells turbine) were built in Islay, UK (1991, [9]-[10]), and more recently in China.

The advantage of the OWC structure is that the relatively weak part of the turbine unit and the motor shaft contact with air instead of wave. Therefore, it has good anti-corrosion performance, low failure rate, and is easy to maintenance. However, its conversion efficiency is low, and construction risk and cost are high due to restricted construction conditions. The typical device is the OWC energy device developed by the Oceanlinx, an Australian company, as shown in figure 3[11]. This also has been done successfully forthe first time in the harbour of Sakata, Japan, in 1990[12], in northern Portugal [13] and in northern Spain [14]. A different geometry for an OWC embedded into a brealonrater was proposed by Boccotti [15].



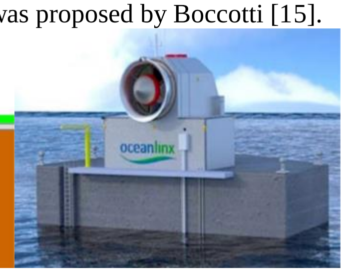


Fig. 2. Schematic diagram of OWC structure Fig. 3. Oceanlinx OWC device

B. *Tilting structure*

Tilting structure of the working principle is to use of wave force impact swing plate, so that the plate swings back and forth around the tilting axis. It converts the wave energy to the kinetic energy of the tilting axis, and then use the hydraulic integration device connected with the tilting shaft to convert the hydraulic energy into electrical energy.

Tilting structure is a power generating device which is fixed and has direct contact with wave. The tilting motion is in line with the characteristics of wave which has low frequency and big thrust. Therefore, the efficiency of tilting wave power device is high, but the maintenance of mechanical and hydraulic mechanism is not easy. The typical device is the UK Oyster VEH [16] Tilting device, as shown in Figure 4 and figure 5[17].

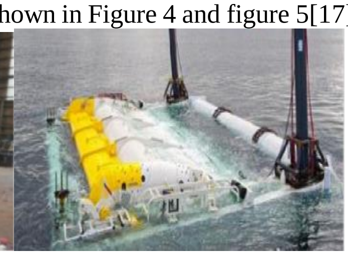


Fig. 4. Oyster 1 VEH device Fig. 5. Oyster 800 VEH device

Oyster is a Bottom hinged buoyancy tilting wave device made by Aquamarine Power. Model tested in 2003, commercialized in 2005, and Oyster1-315kW full scale prototype achieved grid-connected power generation in 2009. At present, there are two Oyster800-800kW full scale prototypes carry out commercial test and grid-connected power generation in European Marine Energy Centre, EMEC in UK.

The Oyster buoyancy tilting is composed of a group of vertically arranged VEH floating pipes. It is connected with the base in the bottom using a hinge, which minimize the weight of the tilting. The inverse tilting is connected with the hydraulic cylinder. Due to the swing of the buoyancy, the wave drives the hydraulic cylinder, and pipes High Pressure Seawater through the water pumping to shore power to drive turbine to generate electricity. Taking advantage of multiple channels, multiple Oyster devices can pump high press water into the same shore-based power generation. The characteristics of Oyster wave power generation device can be summarized as: simple structure, high survivability, shore-based power generation.

C. *Raft structure*

The working principle of raft structure is that when wave rafts are hinged together by hinges, and the energy conversion device is placed at each hinge, the motion of the waves will bend wave raft along the hinge, thereby repeatedly compressing the hydraulic piston and outputting mechanical energy (Figure 6).When the natural frequency of the device is similar or close to that of the wave, the output efficiency of the device reaches highest The advantage of raft technology is that there is only angular displacement between wave rafts. Even in the big waves, the displacement is not too much, which resulting in good performance in challenging wind and wave conditions. The disadvantage is that the device is arranged along the wave direction, and the unit power consumption is larger than that of the vertical wave arrangement, which may cause the equipment cost to be higher.

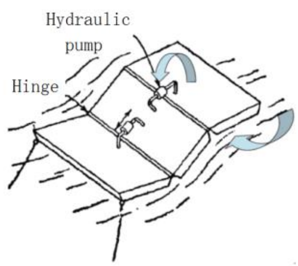


Fig. 6. Schematic diagram of raft structure

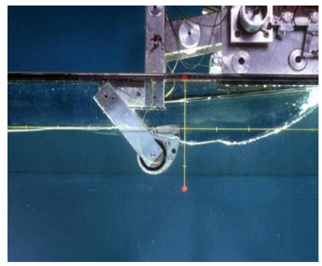
The typical device of the raft structure is the Pelamis raft wave energy device made in UK. The "sea snake" wave power device made in August 2004 by the Pelamis Wave Energy Power, a Scottish company, achieve grid-connected power generation. It is the world's first commercial wave power station. The internal structure is shown in Figure 7.Each buoy has an independent hydraulic cylinder, an accumulator, and a hydraulic motor, with maximum output power of 250 kW (in effective wave height of 5.5 m).The device faces the wave direction. When wave knocks the device, the buoy will bend and drive hydraulic cylinder joints, thereby enabling the device to generate electricity. Figure 8 [18]-[19] shows the field diagram of the second generation Pelamis device [20].

Fig. 7. The internal structure of Pelamis Fig. 8. Generation Pelamis device

D. *Canard structure*

Salter Cam is shown in Figures9 [21].Salter Cam, also known as" the nodding duck, "features an outer shell that rolls around a fixed inner cylinder that is activated by the incoming waves. The power can be captured through the differential rotation between the cylinder and the cam. In this application, the motion of the cam is converted from wave into a hydraulic fluid, and then the hydraulic motor is used to convert the pressurized hydraulic fluid into rotational mechanical energy. Consequently, the rotational mechanical energy is converted to electricity by utilizing electric generators [22].

The typical device of the canard structure is the Canadian WET EnGen canard wave energy device, as shown in figure 10[23].The device is a directional absorption float device whose base is anchored to the bottom of the sea. A long inclined mast extends from the base to the surface, and the absorption float moves up and down along the mast with waves. The mast can be rotated, so that the float can be rotated to face waves from any direction.



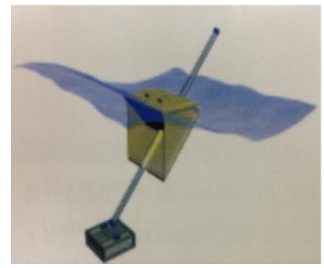


Fig. 9. Schematic diagram of The Duck version Fig. 10. Schematic diagram of WET EnGen

E. *Oscillation float structure*

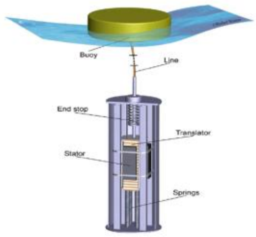
The Oscillator float structure consists of floating body, energy conversion mechanism, generator, protective shell, and other components, as shown in figure 11[24].The floating body works as the wave receiving body[25]. It collects energy and transfer it to energy conversion mechanism, thereby generated stable hydraulic energy. The hydraulic motor converts hydraulic energy into stable rotating mechanical energy, which in turn drives the generator to generate electricity. The hydrodynamics of two-body systems was theoretically analyzed in detail by Falnes [26]. Multi-body wave energy converters raise special control problems [27]-[29].

Oscillator float wave power generating device has many advantages. It has high conversion efficiency and light underwater construction, which reduces the construction difficult and lowers the cost. However, the maintenance and repair of hydraulic drives are difficult, and the entire device is susceptible to seawater corrosion due to its precise sealing [30].

The hydrodynamics of two-body systems was theore-tically analysed in detail by Falnes [31]. Multi-body wave energy converters raise special control problems [32]-[34].

F. *Overtopping converters*

A different way of converting wave energy is to capture the water that is close to the wave crest and introduce it, by over spilling, into a reservoir [35]-[36]. In order to harness the wave energy, wave currents can be funneled into a narrow channel to increase their power and size. The waves can be channeled into a catch basin and used directly to rotate the turbine as shown in Figure 12[37]-[38].This method is more expensive in comparison to the other offshore applications, since it requires building a reservoir to collect the water carried by the waves to drive the turbine. However, all the components of the WEC system are located inland, and this results in easier and less maintenance in comparison to the offshore applications. Additionally, since a reservoir collects the ocean water, the intermittencies can be eliminated with respect to the size of the reservoir. This will create a convenient platform for voltage and frequency regulation. However, it will be more advantageous to build this type of plants in the locations where they have regular and sustaining wave regimes. However, this structure of power station is hard to popularize due to its strict requirements on the terrain. [39]



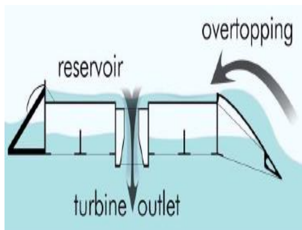


Fig. 11. Swedish heaving buoy Fig. 12. Overtopping WEC: the Wave Dragon

The typical devices of Poly wave reservoir include Wave Dragon, developed by Denmark Wave Company, Mighty whale, the Wave power generation device in Japanese, and Agucadoura wave power station in Portugal [40-42].

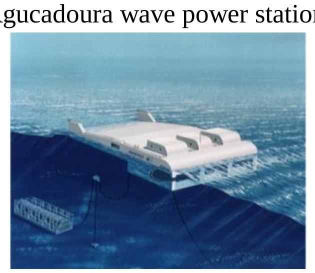


Fig. 13. The Japanese "whale" device Fig. 14. Portugal Agucadoura wave power station

Based on above analysis, and taking the unique condition of tropical ocean reefs into consideration, we have chosen the metrics including area covered, reliability, conversion efficiency, corrosion resistance, and typhoon resistance in order to compare different structures. The result is shown in table 2.Through comprehensive analysis, we conclude that the raft structure is the best choice for the tropical ocean reefs.

Table 2 Comparison of VEH structure type parameters

structure	Area covered	reliability	conversion efficiency	Corrosion resistance	Typhoon resistance
OWC	middle	low	middle	high	middle
Tilting	middle	high	middle	high	low
Raft	low	high	high	high	high
Canard	middle	middle	high	middle	low
Oscillating buoy	low	low	high	low	middle
overtopping	low	high	middle	middle	high

V. CONCLUSION

In summary, wave power generation is the most competitive method to meet the energy demand on tropical island reefs. Given that tropical island reefs have unique climate and terrain conditions, and their energy demand is not too large, the raft wave power device which has high efficiency, small footprint, and high reliability is the best choice. Therefore, the raft wave energy system is more promising to be developed as either a primary or supplementary power source for the tropical island reefs,.

REFERENCES

[1] Mollison D. The prediction of device performance. In: Count B, editor. Power from sea waves. London: Academic Press; 1980. p. 135-72.

[2] Mollison D. Wave climate and the wave power resource. In: Evans DV, Falcao A.F. de O, editors. Hydrodynamics of ocean wave energy utilization. Berlin: Springer; 1986. p. 133-67.

[3] Pontes T, Mollison D, Borge JC, Cavaleri L, Athanassoulis GA. Evaluation of the wave energy resource. In: Proc Workshop Wave Energy R&D, Cork, Ireland European Commission Report No. EUR 15079 EIV; 1993, p. 1-8.

[4] Pontes MT. Assessing the European wave energy resource. Trans ASME J Offshore Mech Arct Eng 1998:120:226-31.

[5] Mollison D. The prediction of device performance. In: Count B, editor. Power from sea waves. London: Academic Press; 1980. p. 135-72.

[6] Mollison D. Wave climate and the wave power resource. In: Evans DV, Falcao A.F. de O, editors.

[7] ZHANG Li-zhen, YANG Xiao-sheng, WANG Shi-Ming, LIANG Yong-cheng. Research Status and Developing Prospect of Ocean Wave Power Generation Device [J]. Hubei Agricultural Sciences, 2011, 50(1).

[8] Mpower Available online: http://www.mpoweruk.com/hydro_power.htm

[9] Whittaker TJT, Mclwaine SJ, Raghunathan S. A review of the Islay shoreline wave power station. In: Proceedings of (First) European Wave Energy Sym-posium; 1993. p. 283-6.

[10] Count BM, Evans DV. The influence of projecting sidewalk on the hydro-dynamic performance of wave energy devices. J Fluid Mech 1984; 145: 361-76.

[11] Oceanlinx. Projects: Our Projects Span Across Eight Different Locations Across the Globe [EB/OL]. (2008-09-04)[2014-08-30]. http://www.oceanlinx.com/projects.

[12] Ohneda H, Igarashi S, Shinbo O, Sekihara S, Suzuki K, Kubota H, et al Construction procedure of a wave power extracting caisson breakwater Tokyo: Proceedings of 3rd Symposium on Ocean Energy Utilization; 1991 p. 171-9.

[13] Martins E, Ramos FS, Carrilho L, Justino P, Gato L, Trigo L, IVeumann F. CeoDouro project: overall design of an OWC in the new Oporto breakwater. In: Proceedings of6th European WaveTidal Energy Conference; 2005. p. 273-80.

[14] Torre-Enciso Y, Ortubia 1, Lopez de Aguileta LI, Marques J. Mutriku wave power plant: from the thinking out to the reality. In: Proceedings 8th European Wave Tidal Energy Conference; 2009, p. 319-29.

[15] Boccotti P. Caisson breakwaters embodying an OWC with a small opening. Part 1: Theory. Ocean Eng 2007; 34: 806-19.

[16] ZHANG Wenxi. YE Jiawei. Research Overview on Pendulum Wave Power Generation Technology [J]. Guangzhou shipbuilding, 2011, 30(1):20-22.

[17] ZHANG Dahai. Reasearch on the Kev Technologies of Wave Energy Converter of Inverse Pendulum [D].ZheJiang University, 2011.

[18] Pizer DJ, Retzler C, Henderson RM, Cowieson FL, Shaw MG, Dickens B, Hart R. Pelamis WEC-recent advances in the numerical and experimental modelling programme. In: Proceedings of 6th European Wave Tidal Energy Conference; 2005. p. 373-8.

[19] Yemm R. Pelamis. In: Cruz J, editor. Ocean wave energy. Berlin: Springer; 2008. p. 304-21.

[20] Pelamis Wave Power Ltd. Pelamis Technology [EB/OL]. (2008-06-27)[2014-08-31].

[21] Salter's Duck. Available from http://tinyurl.com/saltersduck (access date 31 May 2009).
[22] J Ross D. Power from sea waves. Oxford: Oxford University Press; 1995.
[23] OPT. Ocean Power Technologies Announces Results for the Fiscal Fourth Quarter and Full Year Ended April 30, 2014 [EB/OL]. (2014-07-29)[2014-10-01]. http://phx.corporate-ir.net/phoenix.zhtml?c=155437&p=irol-newsArticle&ID=1952733.
[24] Waters R, Stalberg M, Danielsson O, Svensson O, Gustafsson S, Stromstedt E et al. Experimental results from sea trials of an offshore wave energy system. Appl Phys Lett 2007; 90(3) [Art No. 034105].
[25] Elwood D, SchacherA, Rhinefrank K, Prudell J, Yim S, Amon E, et al. Numerical modelling and ocean testing of a direct-drive wave energy device utilizing a permanent magnet linear generator for power take-off. In: Proceedings of 28th International Conference on Ocean Offshore Arctic Engineering, ASME Honolulu, Hawaii: 2009 [Paper No. OMAE2009-791461.
[26] Falnes J. Wave-energy conversion through relative motion between two single-mode oscillating bodies. J Offshore Mech Arctic Eng 1999; 121:32-8.
[27] Korde UA. Phase control of floating bodies from an on-board reference. Appl Ocean Res 200123251-62.
[28] Korde UA. Systems of reactively loaded coupled oscillating bodies in wave energy conversion. Appl Ocean Res 2003; 25:79-91.
[29] Beatty SJ, Buckham BJ, Wild P. Frequency response tuning for a two-body heaving wave energy converter. In: Proceedings of 18th International Off-shore Polar Engineering Conference; 2008. P.342-8.
[30] OPT. Ocean Power Technologies Announces Results for the Fiscal Third Quarter Ended January 31, 2014 [EB/OL]. (2014-03-14)[2014-09-01]. http://phx.corporate-ir.net/phoenix.zhtml?c=155437&p=irol-newsArticle&ID=1908950.
[31] Falnes J. Wave-energy conversion through relative motion between two single-mode oscillating bodies. J Offshore Mech Arctic Eng 1999; 121: 32-8.
[32] Korde UA. Phase control of floating bodies from an on-board reference. Appl Ocean Res 200123251-62.
[33] Korde UA. Systems of reactively loaded coupled oscillating bodies in wave energy conversion. Appl Ocean Res 2003;25: 79-91.
[34] Beatty SJ, Buckham BJ, Wild P. Frequency response tuning for a two-body heaving wave energy converter. In: Proceedings of 18th International Off-shore Polar Engineering Conference; 2008. p. 342-8. Hydrodynamics of ocean wave energy utilization. Berlin: Springer; 1986. p. 133-67.
[35] Margheritini L, Vicinanza D, Frigaard P. Hydraulic characteristics of seaware slot-cone generator pilot plant at Kvitsoy (Norway). In: Proceedings of 7th European Wave Tidal Energy Conference; 2007.
[36] Vicinanza D, Frigaard P. Wave pressure acting on a seawave slot-cone generator. Coastal Eng 2008; 55: 553-68
[37] Wave Dragon. Available from http://tinyurl.com/wavegenl/ (access date 2 Ju1y2008).
[38] Wave Dragon schematic. Available com/wavegen2/ (access date 2 July from http: / /tinyurl.2008).
[39] Technology: Wave Dragon [EB/OL].(2008-07-02)[2014-08-31]. http://www.wavedragon.net/index.php?option=com_content&task=view&id=4&Itemid=35.
[40] Technology: How Oyster wave power works [EB/OL]. (2008-07-01)[2014-08-30].http://www.aquamarinepower.com/technology/how-oyster-wave-power-works.aspx.
[41] ZHANG Li-zhen, YANG Xiao-sheng, WANG Shi-ming, LIANG Yong-cheng. Research Status and Developing Prospect of Ocean Wave Power Generation Device [J]. Hubei Agricultural Sciences, 2011, 50(1).
[42] Technology: How Oyster wave power works [EB/OL].(2008-07-01)[2014-08-30].http://www.aquamarinepower.com/technology/how-oyster-wave-power-works.aspx.