Extended abstract prepare for 27th IWWWFB

Experimental investigation on the power generation performance of floating point absorber wave energy systems

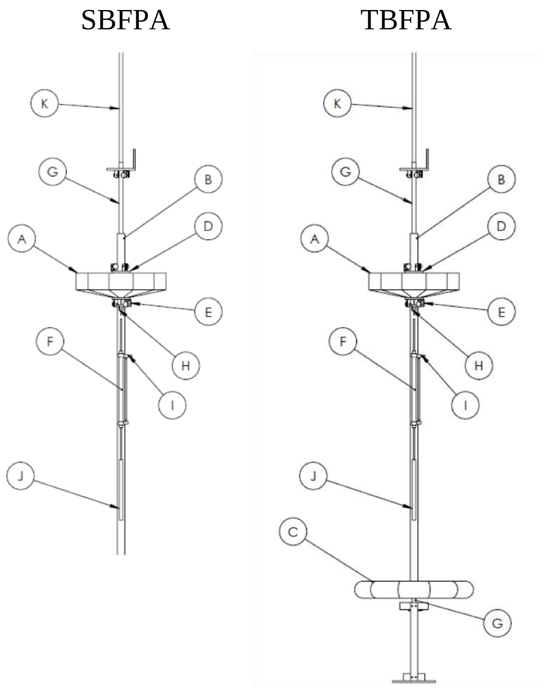
By Ye Li[1], Yi-Hsiang Yu[1], Jeff Epler[2] and Mirko Previsic[2]

1. Introduction

The extraction of energy from ocean waves has gained interest in recent years [1]. Floating-Point Absorber (FPA) is one of the most promising devices among a wide variety of wave energy conversion technologies [2]. Early theoretical studies mainly focused on understanding the hydrodynamics of the system and on predicting the maximum power that be extracted by a heaving body [3–6]. They evolved from the investigation of floating-body interaction in offshore engineering and naval architecture disciplines. Additionally, comprehensive reviews on this topic can be referred to [7,8]. To our best knowledge, no systematical study has been reported about the investigation of the power generation performance of a FPA with a close-to-commercial design. With the support of U.S. Department of Energy, we conducted a series of experimental investigations. Here, we present a preliminary preview of our experimental study and the power extraction performance analysis. Readers who are interested in reliability study can refer to [9], although the device scale is different from what we discussed here.

2. Device Design

Usually, FPA is either a single buoy that reacts against the seabed or a multi-body system that generates energy from the relative motion between the oscillating bodies. The latter are generally designed for deeper water deployment with a depth between 40 meters and 100 meters while the earlier one operates in shallower locations. Here, we consider a Single-Body FPA (SBFPA) system and a Two-Body FPA (TBFPA) system. A 1:33 scale model was built. The details of the model geometry and properties were described in Fig. 1. Both systems contain a float and a central column, and the TBFPA system includes an additional damping plate. The float and the central column are connected with a miniature hydraulic cylinder in closed circuits with a needle valve to provide damping to the relative motion to represent the Power Take-Off (PTO) mechanism. We control the PTO damping by turning the needle valve.



Component	Mass (Kg)
A. Float	3.220
B. Central column	0.745
C. Damping plate	1.108
D. Top roller	0.115
E. Bottom roller	0.117
F Cylinder & clamps	0.205
G. Heave guides	0.116
H. Load cell	0.012
I. Needle Valve	0.015
J. Linear pot (short)	0.077
K. Linear pot (long)	0.114

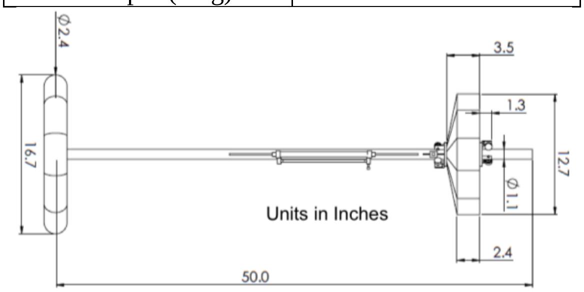


Figure 1. Design of the point absorber: (left) geometry sketch; (right) properties in model scale

[1] National Renewable Energy Laboratory, Golden, CO, USA; the first two authors contribute equally
[2] Re Vision LLC, Sacramento, CA, USA

3. Experimental Setup

The experimental wave tank test was conducted at the wave tank in Scripps Institution of Oceanography at University of California, San Diego in late summer 2011. Figure 2 shows the dimension of the wave tank and the experimental settings. The wave tank is 44.5 meters long, 2.44 meters wide, and the water depth is 1.46 meters. In the design principle, heave is the dominated motion of the system. Thus, in both SBFPA and TBFPA systems, the float is only allowed to move in heave and along the central column via external constraint. In the SBFPA test, the central column was connected to the carriage (a fixed frame). In the TBFPA system, a linear pot is used, and the central column and the damping plate are allowed to move along it.

A linear potentiometer (Fig. 2c) was used throughout the test to record the relative motion between the float and the central column. In order to ensure the linear potentiometer measurement quality, a camera tracking system was also implemented, where four cameras were used for the test and were arranged in a semi-circle around the model (Fig. 2d). The motion tracking system can capture all 6 degree-of-freedom motions, and it shows that motions other than heave are minimized. To evaluate the power generation performance of the system, the PTO force measurement is needed, and the values were obtained using a load cell (Fig. 2b). Also, a National Instruments USB 6009 data acquisition was used with LabVIEW software to record, calibrate, and process the test measurements. The data for each run was sampled at rate of 100Hz for 60 seconds.

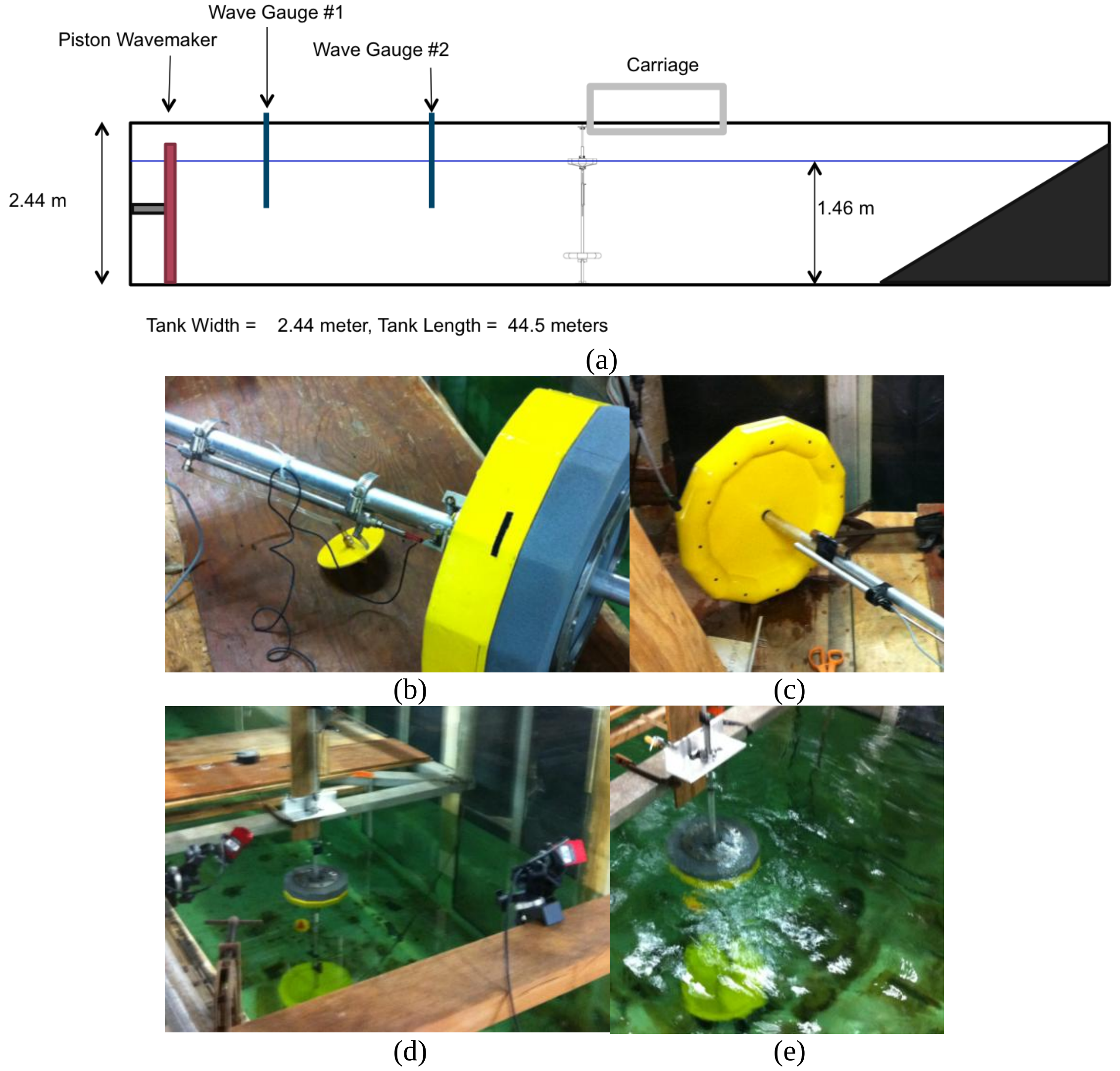


Figure 2. Experimental settings: (a) configuration sketch; (b) load cell; (c) linear potentiometer; (d) camera system; (e) a snap shot

4. Results Discussion

Due to the time constraint and page limitation, we here only show a few preliminary results. Note that all the results are presented in full scale unless mentioned otherwise. The relative velocity of the motion between the float and the central column is calculated by differentiating the motion with respect to time. The power is then calculated by multiplying the load cell force with the relative velocity obtained above.

Figure 3 shows the power generation performance of the SBFPA system in waves with a height of 2 meters. The averaged power that can be extracted by the system is plotted against the wave period. Note that the natural period of the float is around 4.3 sec, obtained from the decay test, and the SBFPA system is not performed close to the resonance in the study. Therefore, the power extraction efficiency (Power/EL, where E is the wave energy flux per unit crest length and L is the capture width) of this SBFPA is only around 10% for a typical wave period of T= 10 sec. The test of the SBFPA system here was conducted to analyze the effect of the PTO damping, and the results can be useful for validating our Computational Fluid Dynamics (CFD) simulation in the future.

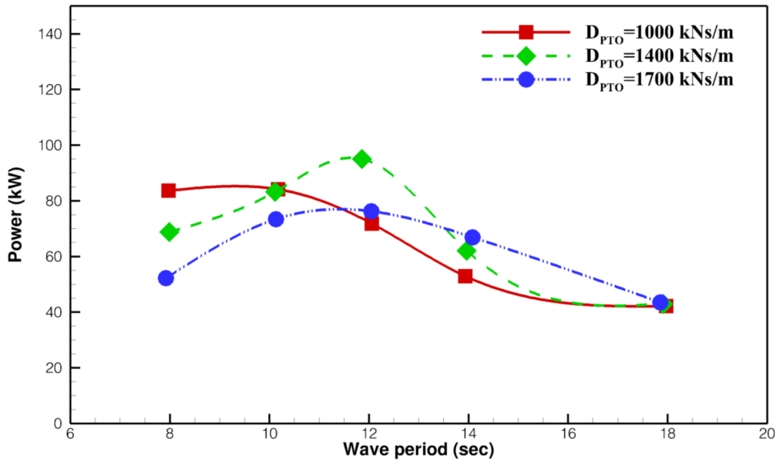


Figure 3. Power generation performance of the SBFPA system (full scale)

The TBSPA system is a commercial like and a more practical design. The additional damping plate provides additional damping to the system and also shifts the natural period to a larger value (around 8 sec). The TBFPA system is designed to have a natural frequency in heave close to the typical peak frequency of real seas in order to maximize the power generation performance. We conducted a series of experimental studies on the power extraction performance of the TBFPA system under waves with a height of 2.5 meters.

Figure 4 shows an example of the time history data from measurements, including the damping (reaction) plate motion, the relative velocity between the float and the central column, the force measurement from the load cell, and the power prediction. To evaluate the power generation performance of the TBFPA system, we plot the averaged power against the incident wave period in Fig. 5. The power is scaled by the square of wave height in order to compare the experimental results with existing CFD simulations, the geometry of which is different from the experimental test due to resource limitation. CFD simulation method can be referred to [10]. The results show that the maximum power extraction efficiency for this TBFPA is around 30%, when the system is close to the resonance. It is noticed that the experimental and CFD results show a similar trend, and both have maximum peak power generation performance close to the natural period of the system. However, the two results have different maximum values. This is expected and maybe caused by (1) different incident wave conditions, where nonlinear waves and FPA motion is essential in waves with larger wave heights [10].; (2) the differences lie in the FPA geometries, where the one used in the experimental test has a larger float height to reduce the chance of wave overtopping.

Given the time and page limitation, here we only provide a very quick overview of our recent study of the performance of floating point absorbers. We shall present more results and discussions in the workshop and summarize them into a full paper shortly afterwards. If possible, the geometry of the FPA in CFD will be the same as ones in experiment. Moreover, we intend to conduct the following works: (1) to optimize device size and geometry to increase the maximum power extraction efficiency; (2) to develop optimal control strategies to have a broader range of wave frequencies that has good energy-absorbing efficiency.

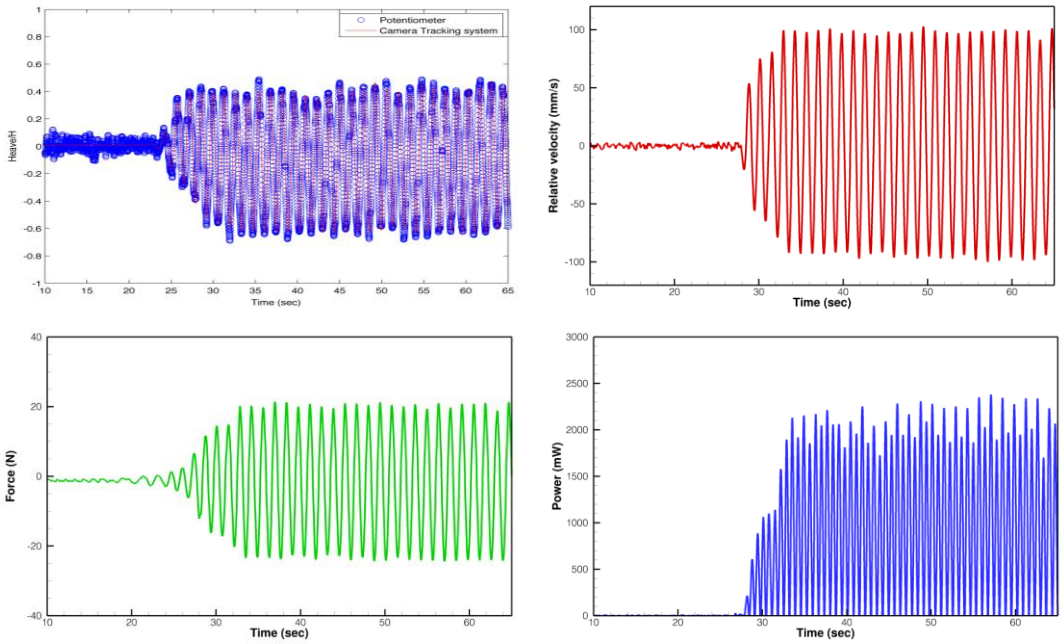


Figure 4. An example of the time history measurement data (T=1.39 sec model scale)

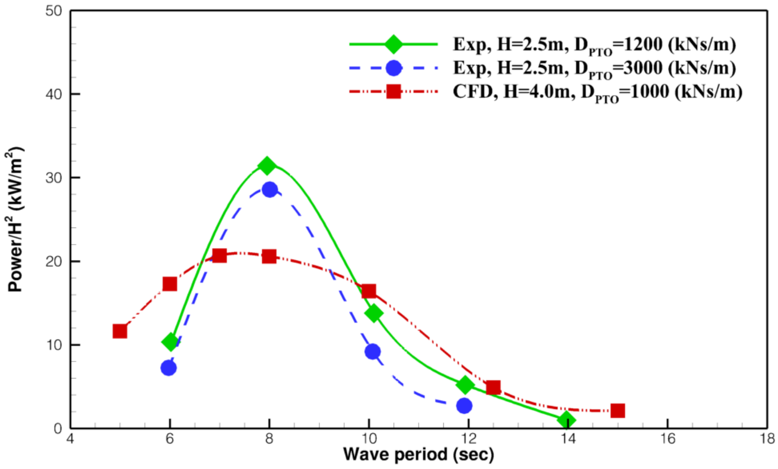


Figure 5. Power generation performance of the TBFPA system (full scale)

Reference

[1] Thorpe T. W., 1999, A brief review of wave energy, Harwell Laboratory, Energy Technology Support Unit.

[2] Falcão A. F. O., 2010, "Wave energy utilization: A review of the technologies," Renewable and Sustainable Energy Reviews, **14**, pp. 899-918.

[3] Budal K., and Falnes J., 1975, "Power generation from ocean waves using a resonant oscillating system," Marine Science Communication, **1**, pp. 269-288.

[4] Evans D. V., 1976, "A theory for wave-power absorption by oscillating bodies," Journal of Fluid Mechanics, **77**(01), pp. 1-25.

[5] Mei C. C., 1976, "Power extraction from water waves," Journal of Ship Research, **20**, pp. 63-66.

[6] Newman J. N., 1976, "The interaction of stationary vessels with regular waves," London, pp. 491-501.

[7] Falnes J., 2002, Ocean waves and oscillating systems, Cambridge University Press.

[8] Falnes J., 2007, "A review of wave-energy extraction," Marine Structures, **20**(4), pp. 185-201.

[9] Li,Y., Yu Y.-H., Nelson,E. Presivic,M., Thresher. "Evaluation of the survivability of the floating point absorber wave energy converter" 31st OMAE, Rio ,Brazil, June 19-24, 2012

[10] Yu Y.-H., and Li Y., 2011, "A RANS Simulation for the Heave Response of a Two-Body Floating Point Wave Absorber," 21st ISOPE, Maui, Hi, United States June 19-24 2011 .