Circular-Slide Wave Energy Converter

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1. Introduction

There are two main types of wave energy converters (WEC) for small-to-moderate power applications in the deep ocean when anchoring is not desired or impractical. The first can be called a "shaking" WEC, which is similar to a rechargeable flashlight that is energized by hand shaking. The second can be called a "direct-drive" WEC, which uses a relatively stationary submerged drag-device to produce a force against surface wave motion to turn a generator. The authors have successfully designed, built, and tested both types for various applications.

The direct-drive type produces much more power per unit weight in all sea conditions than the shaking type; however, in harsh environments, it is preferable to use the shaking type, because it can be hermetically sealed to reduce environmental degradation and extend operational life. A conventional shaking WEC consists of a generator mass that hangs from springs and moves with linear motion in response to wave heaving motion. The natural frequency of a linear, mass-spring system must be close to the predominant wave frequency so that large vibration amplitudes can be achieved for effective energy harvesting. However, ocean wave frequencies are naturally low, so soft springs, with impractically large vertical deflections, are required to achieve resonance. This represents a design weakness.

We suggest a different type of shaking WEC with a mass that slides in a circular trajectory under gravity in response to wave-induced buoy pitch/roll, as illustrated in Fig. 1. This conceptual WEC includes the following major components: sliding mass, circular sliding track, connecting arm, gearbox, generator, and encoder. For protection from the harsh ocean environment, all of the components would be mounted inside a hermetically sealed box.

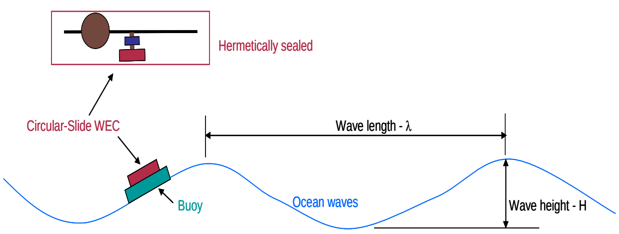

Figure 1. Circular-slide WEC utilizing buoy pitch or roll motion.

2. Description of Circular-Slide WEC

The sliding mass is a weight with a circular or rectangular cross-section that slides on wheels in a low-friction track with ball-bearings on rails. The connecting arm is a light structure that connects the sliding mass to the input shaft of a gearbox. The gearbox increases the rotation speed and drives an electrical generator.

The encoder would be mounted on the gearbox input shaft. The angular displacement of the sliding mass would be measured by the encoder and used for feedback control to create an artificial torsional spring. This spring would make the sliding mass resonate, or move back and forth on the circular track when the buoy pitches or rolls due to wave motions. The angular motion of the sliding mass would be amplified by the gearbox to drive the generator and produce power. The optimal resonating angular amplitude of the mass on the track is ±90°.

The zero reference of the feedback control points to the buoy pitch or roll axis following the wave. When the initial reference is set, the controlled axis may or may not coincide with the actual buoy axis. If they coincide, maximum power would be harvested. Therefore, during online control, the zero reference would be monitored and gradually changed to achieve maximum power.

3. Power Predictions

Expected power for the circular-slide WEC has been derived and shown in the equation below.

$$P = 20\,\pi\,\eta\,M\,R\,H\,/\,T^3$$

where P = average power, watt
M = sliding mass, kg
R = circular track radius, m
H = significant wave height, m
T = dominant wave period, s
η = system efficiency, assumed to be 0.75.

On average, world-wide ocean waves have a significant height of about 2m and a dominant period of about 10s. For those average conditions, our circular-slide WEC would produce average power (in watts) as listed in the following table.

	Radius (m)		
Mass (kg)	0.5	1.0	2.0
25	1	2	5
50	2	5	9
100	5	9	18

4. Summary

We conceptualize a new design and predict performance for a robust circular-slide, wave energy converter for use in small-to-moderate power, deep-ocean applications, such as charging batteries on weather buoys. The predicted average power is directly proportional to the sliding mass, the circular slide track radius, the wave amplitude, and inversely proportional to the wave period cubed.