Abstract

The extraction of useful energy from ocean waves is a tempting prospect. Even before concerns arose about greenhouse gases and global political tensions over energy, people have sought to tame the raw power of the ocean to do useful work. One of the simplest methods to extract energy from an ocean wave is to use a buoyant float anchored to the sea bottom. As waves pass, the float rises and falls. The resultant oscillating tension on the anchor cable can be used to pump water or generate electricity. This research investigated the effect of reducing the dissipation of energy by such a wave-energy device, with the goal of showing how the efficiency of the device can be improved.

3) Introduction

I have been in discussion with a company which has been developing an ocean wave-energy conversion device, with the goal of the discussions being to formalize a consulting
arrangement. I have conceived an idea which could both significantly improve the efficiency and lower the cost of their device. I would like to secure some degree of protection for the invention before I enter into a consulting relationship with this company.

WiSys, the University of Wisconsin System’s agency for protecting and licensing inventions created by UW researchers, provides a process for obtaining one-year Provisional Patents to protect an invention in the short term. WiSys requires detailed documentation of the idea in the form of an Invention Disclosure Report. With the support of this SAIF grant, I worked to complete the work that is necessary to disclose and protect my invention.

The extraction of useful energy from ocean waves has tempted numerous inventors over the centuries. Anybody who has felt the power of the ocean surf has had a tangible experience of the power of ocean waves. Even before depletion of fossil fuels and global political tensions over energy, people have sought to tame the raw power of the ocean to do useful work. One of the simplest methods to extract energy from an ocean wave is to use a buoyant float anchored to the sea bottom. As waves pass, the float rises and falls. The resultant oscillating tension on the anchor cable can be used to drive a pump or spin a generator to pump water or generate electricity. If a pump is used, the resulting high-pressure water can be used to generate fresh water by using a reverse-osmosis filter.

There are several sources of energy in the world’s oceans: temperature gradients, salinity gradients, biomass, tides, currents, and waves. In short, one can exploit potential differences in temperature or salinity to drive an engine, one can harvest plant life and
plankton to create fuel [1], or one can convert the kinetic and potential energy of moving water. In each case, the ultimate source of the energy is the Sun. For ocean waves, the entire surface of the world’s oceans acts like a solar energy collector. This energy is transferred into weather systems, and the resulting winds generate water waves.

![Figure 1. Schematic of a simple buoyant ocean wave-energy converter.](image)

Several techniques have been proposed to harness the energy in these ocean waves. The majority can be categorized as follows: buoyant devices, oscillating water-column devices, and overtopping devices. Buoyant devices were described above, with a float rising and falling with the waves; other buoyant devices use multiple floating bodies moving relative to each other. Oscillating water-column devices use the rising and falling water surface like a piston, which pushes and pulls air through a turbine. Overtopping devices force the waves to break into an elevated reservoir, and then use that water to drive a turbine as it flows back to the sea.

Numerous companies worldwide have pursued the goal of ocean wave-energy extraction. Among the few that are well-funded and poised for commercial success is Ocean Power Technologies, Inc. (OPT) of Pennington, NJ. Their PowerBuoy system is a buoyant
system, similar to the description above. However, as opposed to pulling on a taut anchor line (which can be expensive to install and maintain), the PowerBuoy relies on the difference in motion between a buoyant ring, which follows the waves, and a more massive cylinder, or spar, which stays relatively stationary in the waves. OPT has secured contracts with Total S.A. of France (the world’s 4th-largest publicly traded oil and gas producer) and Iberdrola of Spain (Europe’s 3rd-largest utility), the U.S. Navy, the U.S. Department of Homeland Security, and others for ocean wave-energy conversion installations. [2]

Every buoyant wave-energy device needs something to pull or push against. In the simplest implementation, a buoy pulls against an anchor at the sea bottom. However, this can be expensive to install and maintain, especially in deep water. Some devices avoid this by using several floating bodies that push and pull against each other; this allows the use of a slack anchor line, which is less expensive. The most successful such device is the Pelamis (see Figure 2) from the UK’s Ocean Power Delivery LTD (three 750-kilowatt Pelamis systems are currently being installed off the coast of Portugal). [3] OPT’s PowerBuoy system has some similarities, but is significantly more simple, and in my opinion shows much more promise to be cost-effective. The PowerBuoy uses a ring which follows the wave surface; this pushes and pulls against a central cylinder (a “spar buoy”) which is relatively motionless in the waves. A proprietary electric generator is driven by the relative motion between the ring and the spar (see Figure 3).
Figure 2. Sketch of the Pelamis wave-energy converter. Generators are driven by the relative pitching motions of the barge segments.

In order to make the central spar buoy steady in waves so that the buoyant ring has something to push against, the spar must be narrow (hence the cylindrical shape) and it must have a large amount of inertia. This inertia can be provided by making the spar massive. However, a large mass means a large quantity of steel, which drives up the cost of the device. To avoid this, OPT uses a “heave plate”, a circular plate suspended below the spar buoy. Motion of this plate moves a large amount of water along with the plate, greatly increasing the inertia of the buoy. Spar buoys with heave plates are used commonly in the offshore oil and gas industry; they provide a stable platform at the surface for deepwater wells. [4] However, these heave plates have another very significant effect: drag, which dissipates energy. This is beneficial for an oil platform, but obviously counter-productive for a wave-energy device.
I have come up with an idea to significantly improve the efficiency and lower the cost of OPT’s PowerBuoy device, as well as other buoyant ocean wave-energy conversion devices. My invention will replace the heave plate; it will add inertia to the spar buoy without adding significant drag (energy dissipation). It will reduce the mass of the structure, thus decreasing the cost.


McCormick [6] wrote perhaps the best-known survey of the state of the art in 1981. Since then, the European Wave Energy Conference series has collected a great deal of knowledge in this field. Kraemer [7] analyzed a hinged-barge wave-energy system and
proposed improvements based on matching the geometry of the system to the expected wave climate. The Electric Power Research Institute [8] has done a great deal of work in surveying the current potential for renewable energy in general, including ocean wave energy.

Cavaleri and Mollo-Christensen [4] looked at the effects of heave plates on the response of spar buoys in waves. This problem has been well-studied, both theoretically and experimentally. A more recent study was done by Tao and Cai [9]. Prislin, Blevins, and Halkyard [10] studied square damping plates, while Thiagarajan et al. [11] looked at plates of varying geometries. Lake, He, Troesch, Perlin, and Thiagarajan [12] studied numerical estimates of the inertia and drag forces on spar buoys.

**Description of investigation**

A simple simulation of the device was created by an undergraduate student using the software package WorkingModel 2D. This software is used in several UWP courses, including Mechanical Engineering 3030 Dynamical Systems. This simulation modeled the energy output of a device that is similar to OPT’s PowerBuoy system, which extracts energy from the relative motions of two floating bodies. The simulation demonstrated the energy output improvement which results from reducing the drag on the device, which is a result of my invention.

Finally, while the nature of this proposal makes it very difficult to involve students at this stage in the process, one student who has knowledge of the computer application WorkingModel 2D (used in the Mechanical Engineering program here at UWP) was instrumental in this project.
Results

The simulation results show a 21% improvement in the power output of the improved system over the existing system at a given sea state. Figure 5 shows that if the damping plate were removed from the current system, lowering the inertia and the damping of the system, the result would be a loss of power. However, if the inertia could be restored
without adding damping to the system, the power would be significantly increased over the original system.

Figure 5. Results of the simulation, showing improvement due to the proposed modification.

Disclosure of the Project Results

The results of this research project were shared with colleagues and students at the UWP Research/Poster Day in the spring of 2008. Furthermore, in the fall of 2008, I plan to make a presentation to students and colleagues at a meeting of the local chapter of the American Society for Mechanical Engineers (ASME) on campus.

References

Electricity Generation,”


