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New and Renewable Energy Generation from Sea Wave Energy Using a Physical Laboratory Model

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Abstract

Energy is dissipated in different forms of consumption by all societies consume. However, most of the energy form used is non-renewable sources (currently science), such as oil. In return, the orientation was to displace these non-renewable forms with other renewable green energy types, for example, wind, sun, sea, or ocean. The experiments and trials covering the exploitation of seawater are few. Some of them exploited the tide either took advantage of the waves' energy, as the experience addressed in this paper. This research presents a physical model experiment to convert wave energy to electrical energy. The experiments took place in a recirculation open channel flume located in the Hydraulics Laboratory of the Higher Institute of Engineering in El Shorouk Academy. The physical model divided into a rectangular buoy made of plastic and compressed with air, and four generators installed mid-length of a framed wood surrounding the rectangular buoy. Furthermore, the buoy's upward and downward movement following the rise and fall of the waves associated with the two-way gear will rotate the shaft, which produces the generator's electricity.

Keywords - *Wave energy, physical model, electrical Energy, floating breakwater, dynamo, electricity, and energy transmission.*

I. INTRODUCTION

Wave energy is generated by air pressure difference from the opposite direction of the wind and the lower wave curve, facing the friction force between the wind and water. The resulting energy depends on the wavelength, frequency speed, and height, and this Energy is exploited exclusively in the generation of electricity, water desalination, or pumping water. Different scientists experienced and explored researches regarding how to generate electricity from wave energy. **MasjonoMuchtar et al. (2016)** presented an experiment for a physical model of wave energy converter based on the water mass vertical movement to be converted to renewable energy. Wave Roller Device for Power Generation was presented by **WassimChehaze et al. (2016)**. **Erik Lejerskog et al. (2015)** presented experimental results based on power absorption from a wave energy converter at the Lysekill wave energy research site. International Conference for Alternative Energy in Developing Countries and Emerging Economies was studied by **S.Chandrasekaran and B. Raghavi. (2015)**, Developing Wave Energy in Mediterranean sea, Analysis and Examination of Other Non-Technological Barriers to The Implementation and Sustainable Development for Wave Energy, **E. Papadopoulos and C. Synolakis (2013)**. **Monica D. Pagnotta (2009)** compared the cost of energy wind-generated electricity indicates COE of Ocean wave energy is expected to decline over time, similar to wind energy. B. Drew, A R Plummer, and MN Sahinkaya (2009) presented a wave energy converter technology. **Michailides and Angelides (2012)** introduced a new type of flexible floating breakwater (FFB), which represents not only a shore protection structure but also a wave energy device. In this system, wave energy can be captured through the relative motion of adjacent floating modules of FFBs. The hydrodynamic performance of the FFB under power take-off (PTO) damping was investigated based on linear hydro elastic theory. The results showed that it is possible to realize the function of wave energy utilization and desired-level wave attenuation simultaneously. **Vicinanza et al.(2014)** combined rubble mound breakwaters and WECs innovatively. Wave energy is extracted by collecting waves overtopping in a front reservoir, by which turbines are driven in the process of returning the water to the sea.

II. EXPERIMENTAL WORK

Experiments were performed in a wave flume 12.0 m long, 50 cm width, and 60 cm depth. The side walls are glass panels. The water depth is 23cm, a hydraulic piston wave generator to generate waves with variable height, length, and periodic time as in fig.(1) and the wave generator in fig. (2), also wave period and Sonic Wave Sensor XB measures wavelength.

Fig.(1) General photo of the experimental Wave Flume.

Fig.(2) View of the Wave generator.

A. Sonic Wave Sensor XB

The Ocean Sensor Systems wireless Sonic Wave Sensor XB, as in fig.(3), is used mostly to provide high-resolution measurements of Intracoastal and wave tank waves. Waves were measured from sub-millimeter to several hundred centimeters at a data rate up to 32 Hz. The used instrument was capable of operating for nearly a few months on two standard alkaline cell batteries. It can collect data continuously or in a burst sampling mode, sampling for short periods and then into low power sleep mode. This Sonic Wave Sensor is very robust with solid-state electronics sealed in a waterproof housing. Time-stamped data can be used to synchronize up to 8 Sonic Wave Sensor XBs for directional wave measurements. The basic operating principle is to measure the ultrasound travel time. After that, the results were scaled with a Micro Processer in the unit and then transmitted over this wireless network to an Xbee USB adapter connected with it. A Windows USB to Serial Converter (driver) connects the USB Adapter port to the User Interface Software (GUI) to be reported in the computer system. When mounting that Wave Sensor, a level should be used to ensure it is all time vertical. The unit should be mounted such that the ultrasonic air space is least than approximately 0.25 meters away from any nearest objects. However, a flat vertical surface may be closer in some cases. The unit should stay at least 0.2 meters above the water. Sonic Wave Sensor used to measure six different heights of the wave as in fig. (4)

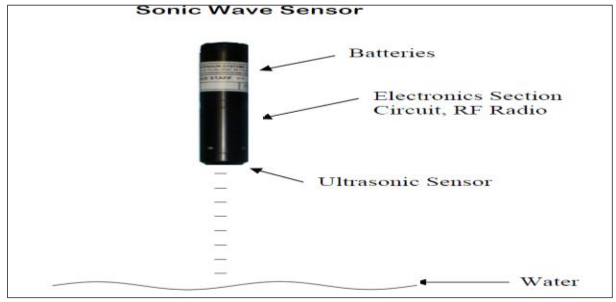
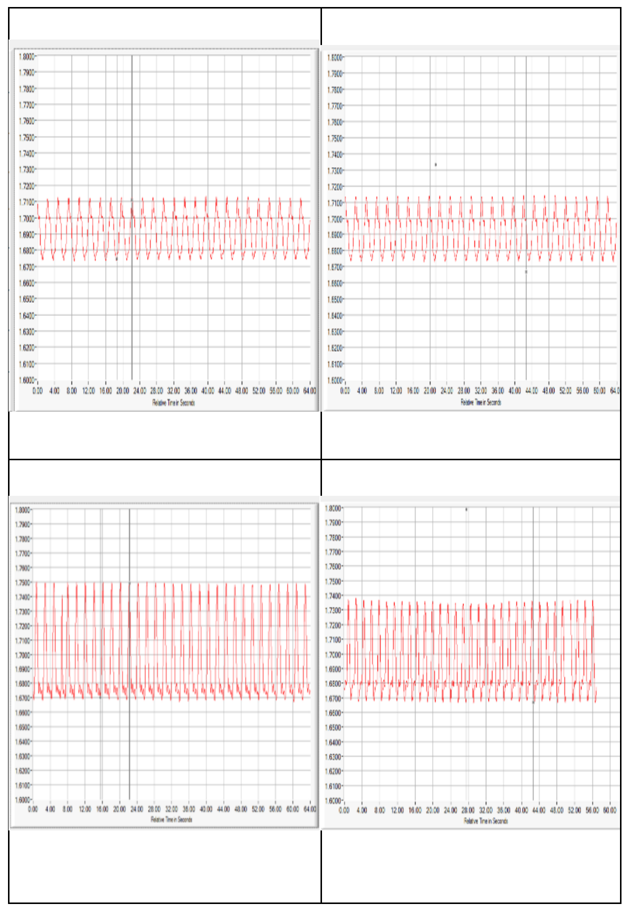


Fig.(3) The Ocean Sensor instrument wireless Sonic



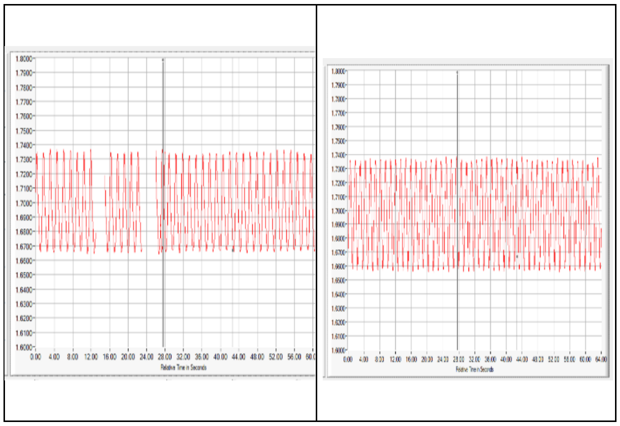


Fig.(4)Six different wave heights measured by Sonic XB Wave Sensor

B. Design of the Physical model wave Converter

The suggested device's experimental design can be divided into a rectangular buoy made of plastic and compressed by air. Wood frame 85 cm long and 49 cm wide. Four generators were installed mid-length of the frame. The generator is used in a synchronous magnetic motor of the fixed type, shown in Fig. (5). Each generator is connected to 4 Diodes and a Capacitor to convert the AC voltage into pulsed DC. The two capacitors were also used to store this Energy. The resulting DC is suitable for power circuits that normally use batteries. The wave height was varied from 4cm to 8cm**.**

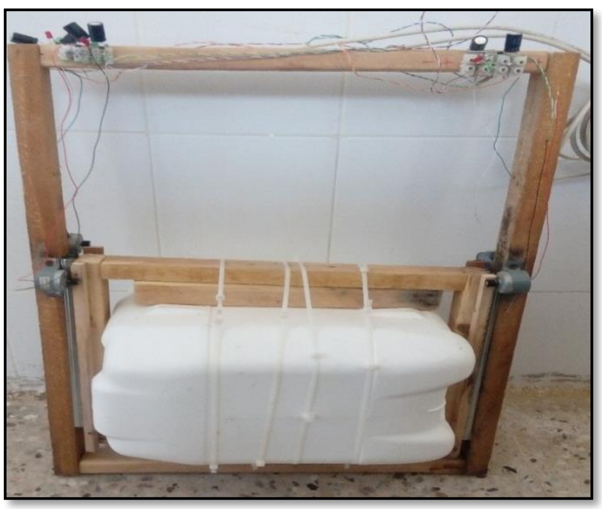


Fig. (5)The experimental shape of the suggested device

C. Analysis, Results and Discussion

The different heights of waves at constant water depth were studied. Many relations were derived and plotted to improve the reality of converting the wave energy to realize the effect of this power. One of these relations is the relationship between the (volt) and the dimensionless ratio (D/L) is shown in fig. (6), where (d) is the depth of water and (L) is the wavelength. Moreover, the relationship between relative (height/length) and relative (wave energy/elec. Energy) as illustrated in fig. (7). Finally, it was found that, by increasing the wave height, the generated electrical Energy increased, and the tested small lamps were lighted during the movement of the suggested device.

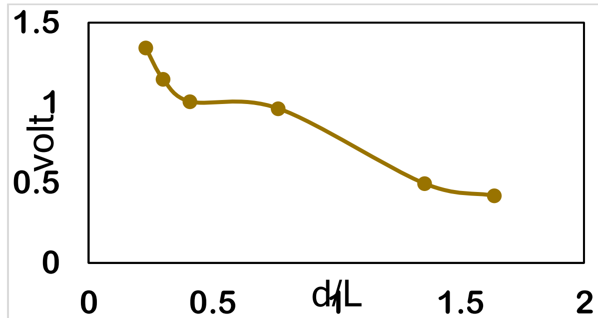


Fig. (6) Relation between (volt) and (D/L)when using four dynamos.

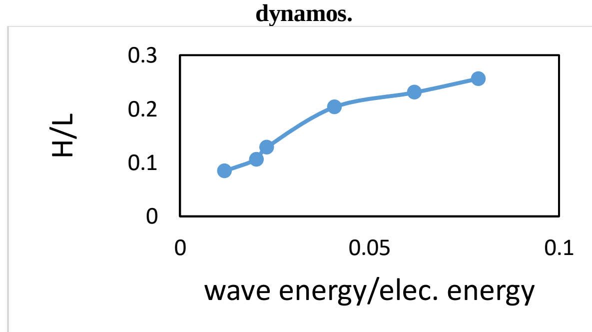


Fig. (7) Relation between H/Land relative (wave energy/elec. energy)when using four dynamos.

The experimental results also can be tabulated in the table (1).

Table (1) the experimental results

Wave height (m)	wavelength (m)	Time (sec)	Wave Energy (watt)	Electric Energy (watt)
0.084	0.9984	0.8	8.65242	0.569856
0.081	0.7644	0.7	8.04542625	0.399504
0.072	0.5616	0.583	6.35688	0.278208
0.068	0.3	0.5	5.67018	0.080976
0.046	0.1996	0.4083	2.594745	0.047616
0.036	0.1404	0.3417	1.58922	0.02016

D. Empirical Equation for electric Energy

A multiple linear regression analysis was used to correlate the relative Energy with other independent parameters to deduce an empirical equation. The correlation coefficients and stander errors of Equation (1) are (99.7 %, 0.002). The measured data are also to be compared to the predicted data, so they were nearly the same as in Fig. (8).

Eq. (1) .... $\frac{wave\ power}{elec.\ power} = -0.02864 + 0.119533\ \frac{H}{L} + 0.012155\frac{H}{d}$

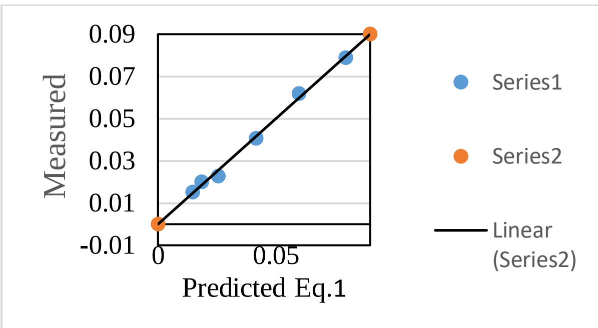


Fig. (8). Predicted values of Eq. (1) versus measured data for relative $\frac{wave\ power}{elec.\ power}$

E. Percentage of energy loss by the Physical model

At the same time, as a consequence of using this model for producing electrical energy, it can play another role of decreasing the Energy transmitted by using the model as a floating breakwater, so by measuring the transmitted wave height by another Sonic Wave Sensor XB to recognize the percentage of Energy transmitted as shown in Figure (9).

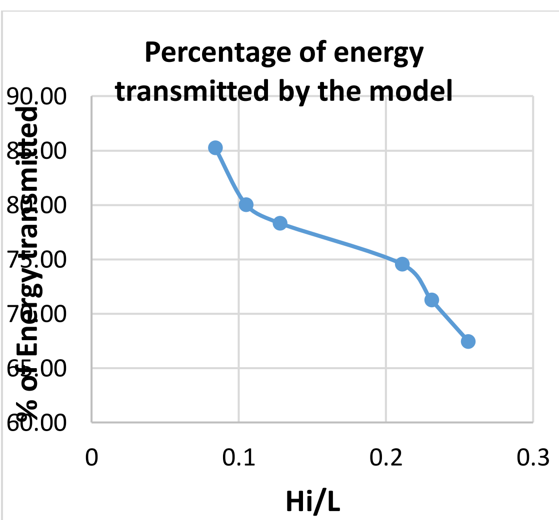


Figure (9) the relation between % of Energy transmitted and Hi/L

Using this physical model, we can calculate wave coefficients (Cr, Ct, and Cd) as shown in table (2).

Table (2) wave Coefficients and wave energy loss and transmitted

Hi/L	Ct	Cr	Cd	% of Wave energy loss	% of transmitted wave energy
0.084	0.923259	0.035	0.382582	93.41	85.24
0.105	0.894521	0.032	0.44588	95.03	80.02
0.128	0.884933	0.03	0.464751	95.62	78.31
0.211	0.863416	0.028	0.503715	98.57	74.55
0.231	0.844149	0.026	0.535478	98.36	71.26
0.256	0.821333	0.025	0.569901	98.73	67.46

So from table (2), we can show different wave Coefficients of (dissipated, reflected, and transmitted) for different wave steepness and choosing minimum and maximum wave heights exposed to the model.

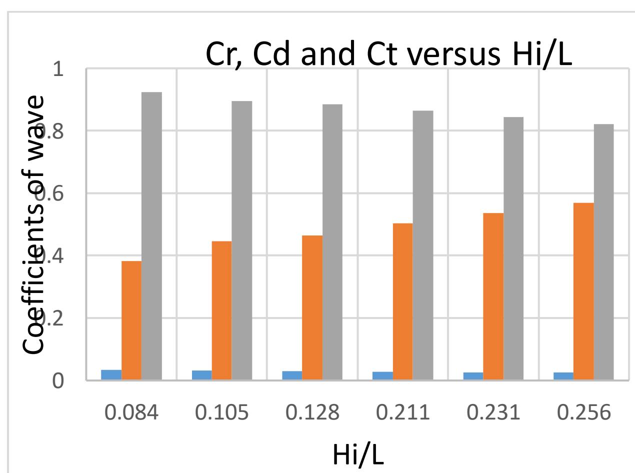


Figure (10) different wave coefficients versus Hi/L

Figure (11) shows the percentage of wave energy used to produce electrical energy from the physical model.

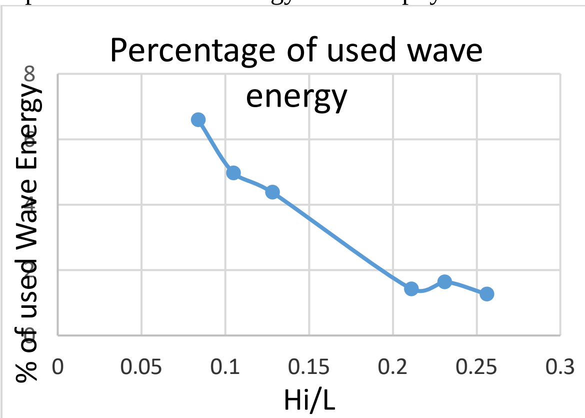


Figure (11) the relation of % of used wave energy versus Hi/L

III. CONCLUSION

The objective of this study was concluded as follows:

By testing this physical model with a constant depth of water and different wave (height, length, and time), it was shown that increasing the wave height, decreasing of wavelength and time that had led to producing maximum energy, when the physical model was up and down. This was mainly due to that the lifting force of the buoy exerted by the wave energy. So approximately only 7 % benefit of maximum wave energy was used for producing electricity. On the other hand, the percentage of Energy transmitted for minimum and maximum incident wave height ranged between 67 and 85 % as the physical model worked as a floating breakwater.

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