Jurnal Mekanikal
June 2005, No. 19, 84 – 94

HYDRAULIC MODEL TEST OF WAVE ENERGY CONVERSION

Arief Suroso
Department of Ocean Engineering
Sepuluh Nopember Institute of Technology,
Surabaya, Indonesia

ABSTRACT

This paper reports the experimental study of wave energy conversion system. The Oscillating Water Column (OWC) has been selected as the primary object of the experimental research. More over, the experimental is a serial research for studying the performance of the OWC. Different models of the OWC have been tested in the previous research. The research reported in the paper tried to apply the reflector in the rear bottom of the cylinder to improve the poor efficiency in the previous models test. The experiment is performed by placing the model in the flume tank and slammed by water wave varied at some wave heights and periods. The reflector position can be changed its slope to obtain the best position for the maximum efficiency. The experimental result indicated that efficiency of the OWC with reflector is better than the OWC without reflector. The model with reflector slope of 45^0 produced better efficiency compared to the remaining slope. The efficiency for model with reflector increases almost double than the efficiency of the model without reflector (previous experiment).

Keyword: *Oscillating Water Column (OWC), orifice, reflector*

1.0 INTRODUCTION

Indonesia as a maritime country, its territory consists of 2/3 part of ocean waters. The Indonesian coastline is the second largest in the world. The coastline is about 80,000 km. There exists a great potential for extracting its energy from large waves, particularly those occurring along the west coast of Sumatra Island and the south coast of Java up to The Nusa Tenggara Isle, surrounding the Natuna Isle and in the region of the East of Indonesia. However, there is little research being carried out on this potential of the wave energy

This paper reports results of all experiment carried in the flume tank to test of one type of wave energy conversion system; the Oscillating Water Column (OWC).

The original OWC system was modified by installing a reflector for increasing the efficiency performance of the model.

2.0 MECHANISM OF OSCILLATING WATER COLUMN (OWC)

The OWC is one of the wave energy conversion systems for converting the wave energy into other useful forms of energy such as electricity, water pumping, etc. The OWC consists of an open-bottom cylindrically tube with a dome shaped cap.

The OWC, with its tube partly submerged in the water, can be placed as a fixed or floating structure in the sea. When the wave slammed the OWC, the water in the tube will move up/down. The moving-up water in the tube causes the air above the water to compress the air causing it to flow up through the orifice at the centre of the dome- shaped cap. The orifice's diameter is very small compared to the tube's diameter thus increasing the speed of air flow. The ratio between the cross-sectional area of the orifice and the tube is more than 1/100. The air passes through the turbine connected to the electrical generator (Figure 1)

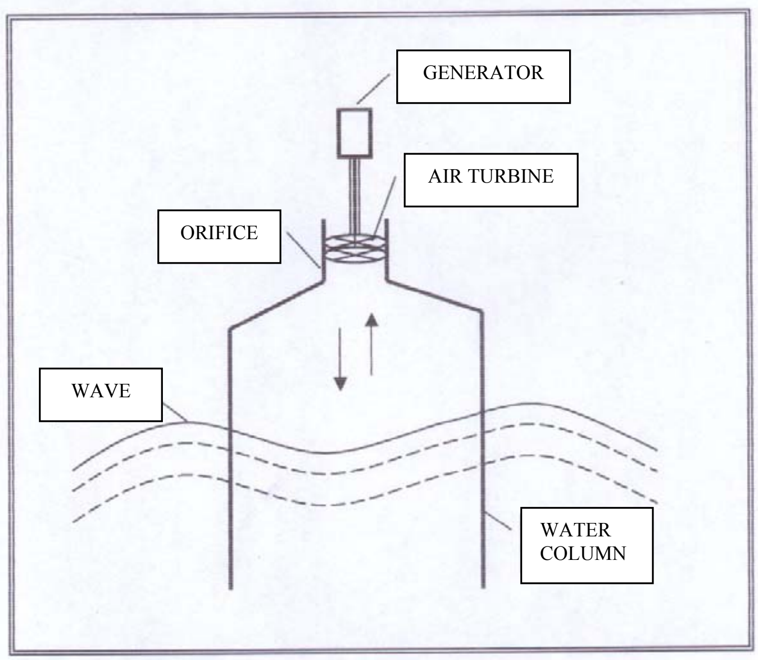


Figure 1: Concept of the oscillating water column

3.0 THE DEVELOPMENT WAVE ENERGY CONVERSION SYSTEMS

Compared to other marine energy resources, wave energy has been attracted to the many researchers. The idea of converting the energy of water wave into useful energy forms is not new. There are techniques that were first patented in the nineteenth century. Although there are over 1000 patented wave energy conversion techniques in the world, many of them do not consider the basic element of ocean-hydrodynamics [1].

The OWC is attractive due to its simple design, reliability and minimum moving parts. The most contemporary use of this phenomenon in wave energy conversion is due to effort Masuda (1971) of Japan Marine Science and Technology Centre. Masuda has been successful in wave energy conversion system designed to provide power to navigation aids such as light buoy.

McCormick [2] theoretically studied with monochromatic wave and his study resulted the graphically correlation between power and wave high and period. Zheng [3] reported the experimental research of prototype of Oscillating Water Column (OWC) in China. The experiment was conducted in a 70m x 1.5m x 1.5m regular Flume tank. The model was composed of three parts: chamber, harbour and two modules of rock bank next to the device**.** Watanabe, et-al [4] has also experimentally and theoretically studied of the OWC in Japan. Those investigators considered that the OWC is the most promising type at present. However because of reciprocating of airflow, the system must be equipped with a special turbine. The authors have invented a new activated generator system. Hiromoto [5] carried out an experiment of the system. The experiment was conducted with a full scale of experimental tanker ship called *Kaimei* in Japan. Xiangying, et-al (1989) [6] from the Ocean University of Qingdau China, theoretical studied the OWC with lateral entrance. The theoretical method they proposed can by used to calculate the efficiency of the OWC. Just after 1995, Suroso [7-10] from *Sepuluh Nopember* Institute of Technology, Indonesia interested on the wave energy conversion systems. He began to study of the possibility of extracting the energy from Indonesian seawater. His study concluded that the OWS is the suitable type for Indonesian sea waters for the reasons of: simple design, reliability, easy construction and installation and appropriate technology for developing country such as Indonesia. One weakness of OWC is its poor efficiency. Therefore, Suroso [7-10] conducted a series of experiment to improve the efficiency of OWC. The present paper is part of this effort.

4.0 HYDRAULIC MODEL TEST

The experiment was conducted in a 20.0m x 1.0m x 1.0m wave flume. Figure 2 illustrates the installation of hydraulic model test. The capacitance type of wave probe measured the incident wave. A simple sensor tool for measuring the air pressure which come out from the orifice. The sensor consists of a long plastic pipe with very small diameter. The end of the pipe was fitted on the orifice while the other end was bent as ‘U’ configuration. Colour water fills the pipe for easy investigation. Millimetre paper is placed behind the ‘U’ pipe for recording.

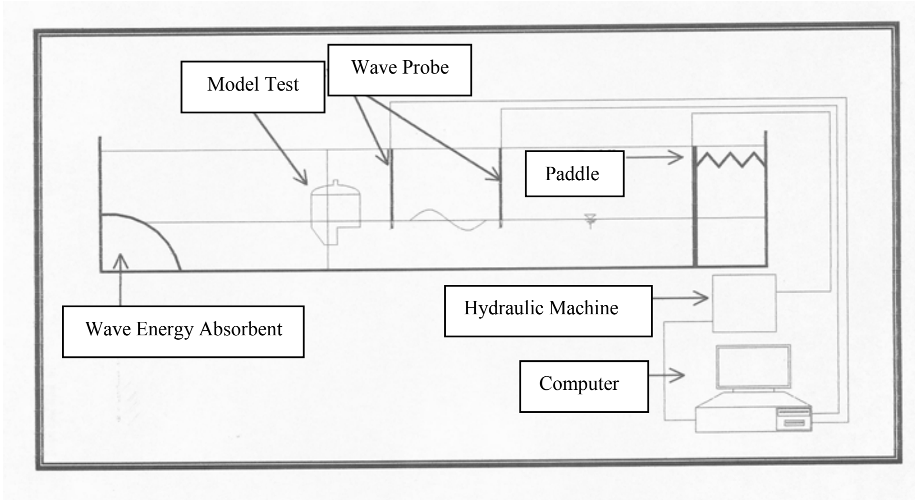


Figure 2: The installation of hydraulic model test

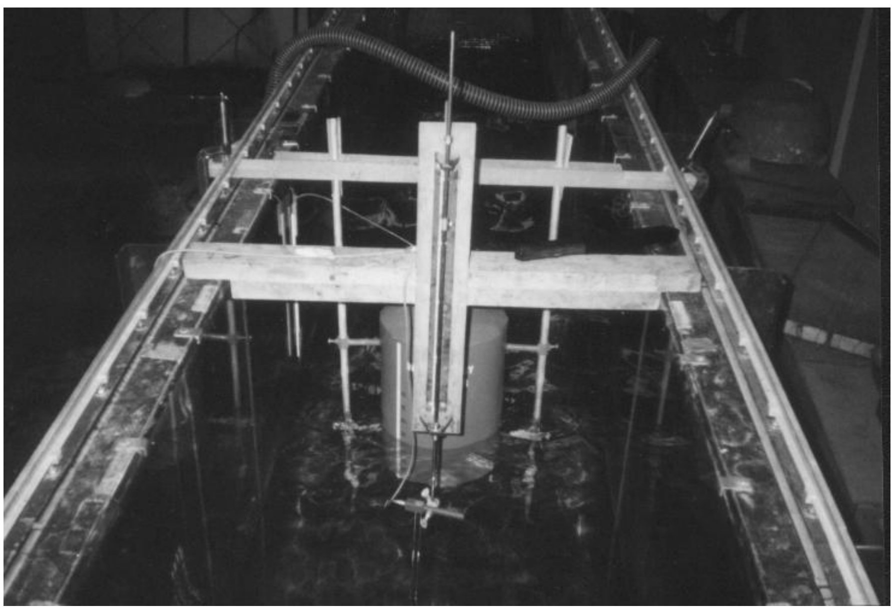


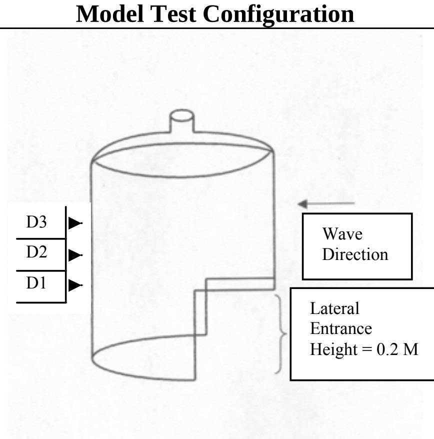
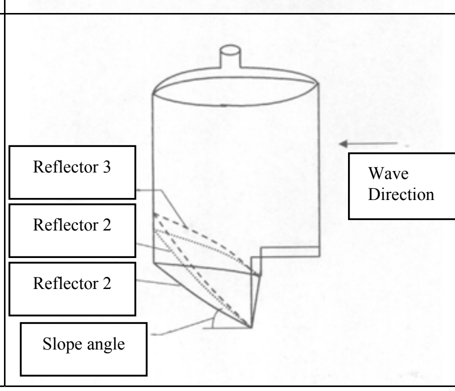
Figure 3: Bird view of the Model Tested in The Flume Tank

5.0 EXPERIMENTAL PROCCEDURE

The purpose of the experiment was to investigate and compare the hydrodynamic performance of two OWC models, one without reflector and one with reflector. The model scale is 1/ 12.5. The experimental condition is shown in Table 1.

Figure 4: Photo of the Model Test shows the Slope of the Reflector

Table 1: Experimental condition

No	Model Test Configuration	Specifications
1.		Model without reflector Water Column Height = 0.80 M Diameter of Water Column= 0.40 M Diameter of Orifice = 0.04 M Height of Lateral Entrance = 0.20M Water Depth D_1 = 0.20 M D_2 = 0.30 M D_3 = 0.40 M
2.		Model with reflector Three (3) different position of reflector with slope angle (β) of 20^o (Reflector 1) 45^o (Reflector 2) 60^o (Reflector 3) Reflector 2 was fitted after reflector 1 finishes to be tested. The same method was applied for reflector 3

The experimental procedures as follows:
Firstly, all sensors were calibrated with the standard calibration work. Each model was tested at three different water depths. For each experiment, a pair of wave heights and periods was applied to the model and change of water level in 'U' pipe was recorded and subsequently converted into pressure (Figure 6).

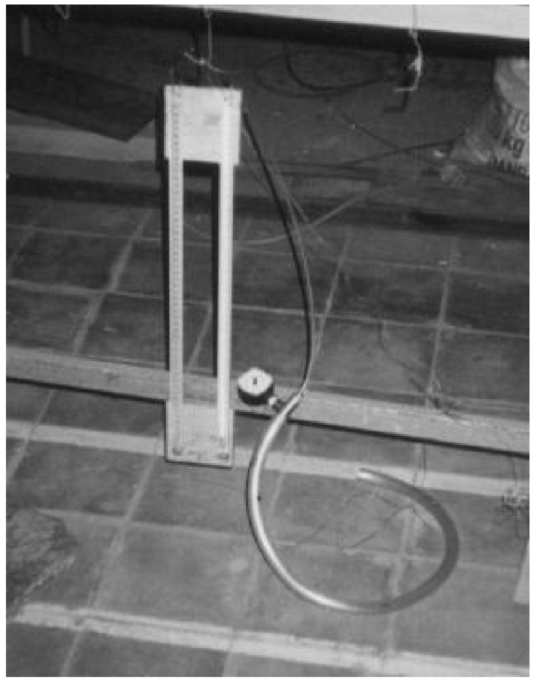


Figure 5: 'U' pipe equipment shows the manometer for calibration work

The efficiency is obtained from the ratio between the power from the orifice and the power from the incident wave or can be represented as the following equation.

$$\eta = \frac{pQ}{(1/8).\rho.g.H^2.\lambda.b} \tag{1}$$

Where:
p = power from the orifice (g cm^2)
Q = volume rate of air flow (m^3/sec)
ρ = mass density of water (kg/m^3)
g = gravitational constant (m/sec^2)
H = wave height in the flume tank (m)
λ = wave length (m)
b = width of the model (m)

6.0 EXPERIMENTAL RESULTS

From the experimental carried out, which are the values of the pressure come out from the orifice were then be evaluated. The evaluation is graphic relation between the pressures with the changes of wave height and period. The relation also applied between the pressure and the depth of the model. The dimensionless graphs are also given for general use. Several graphic of the experiment result are given in Figures 6 – 11.

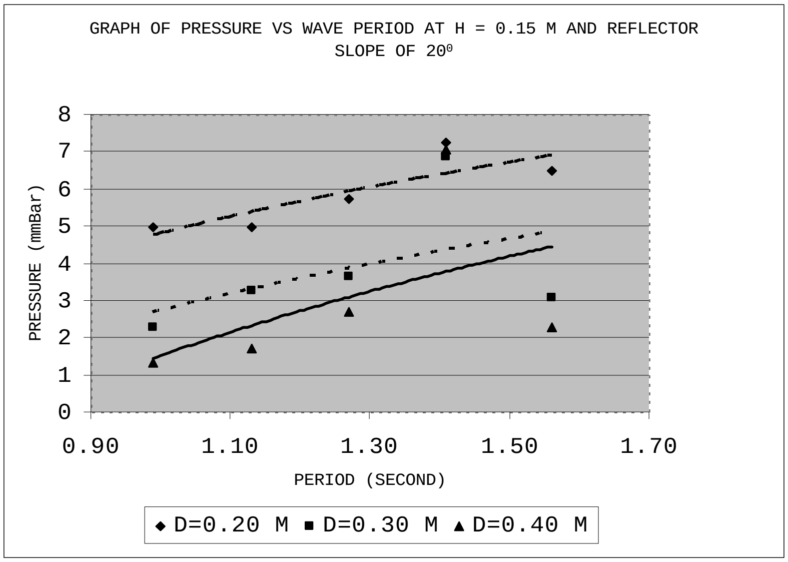


Figure 6: Graph of the relation between pressure and wave period at H= 015 M and reflector slope of 20^o

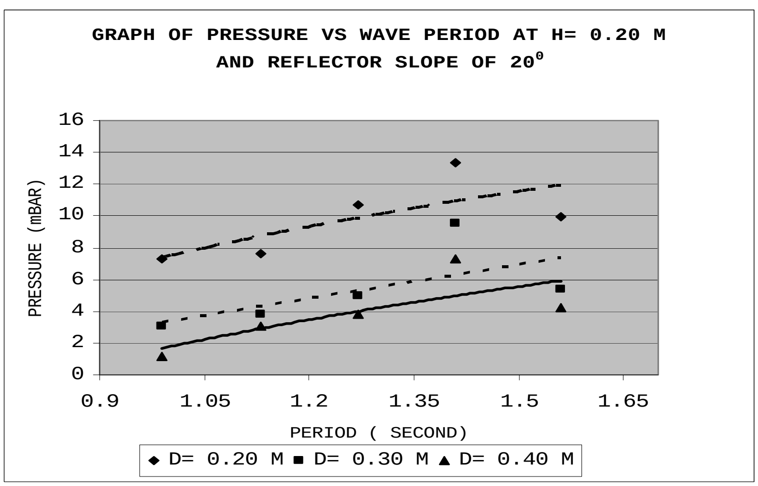


Figure 7: Graph of the relation between pressure and wave period at H= 0.20 M

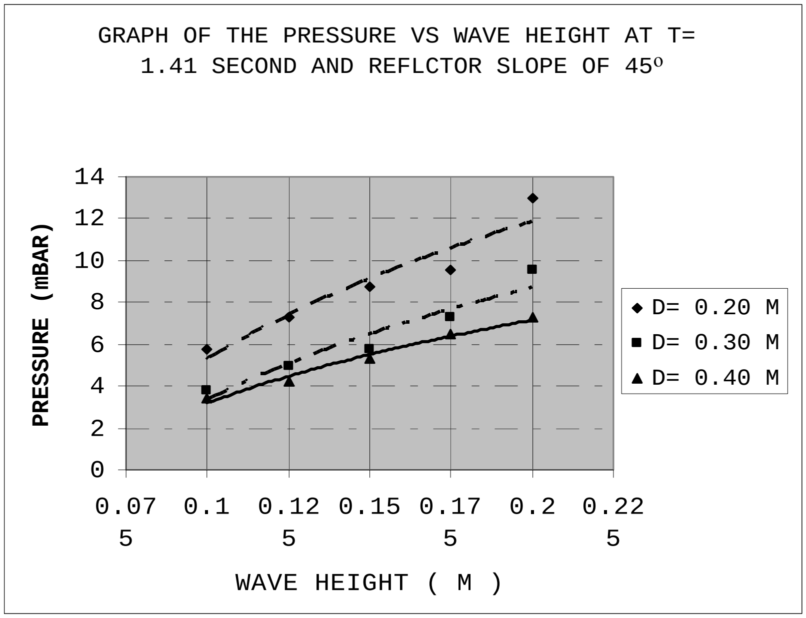


Figure 8: Graph of the relation between pressure and wave period at H=0.20 M and reflector slope of 45°

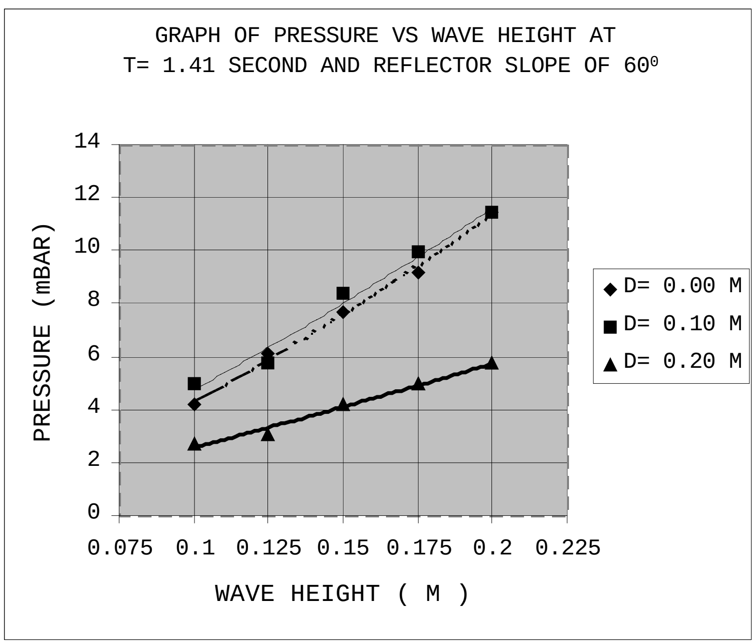


Figure 9: Graph of the Relation between pressure and wave height at T = 1.41 second

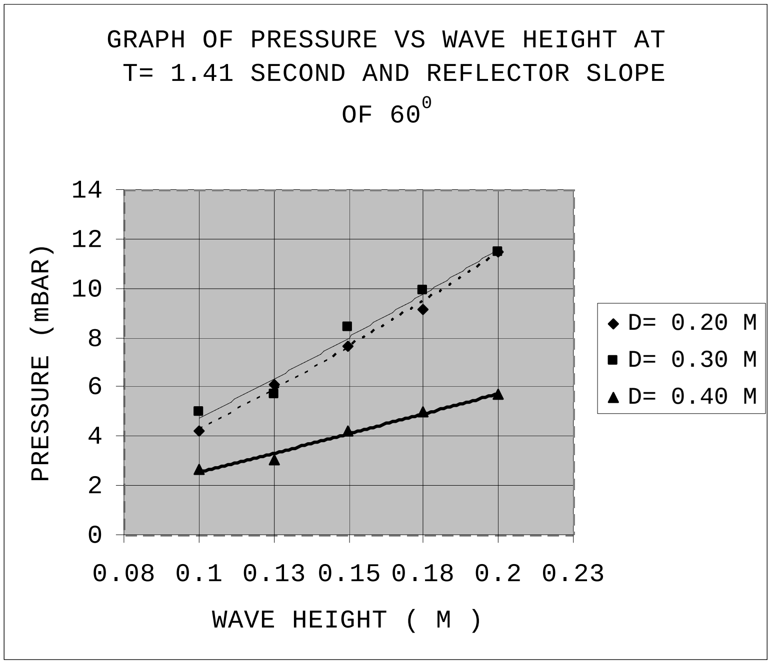


Figure 10: Graph of the relation between Pressure and wave height at T = 1/41 second and Reflector Slope of 60^o

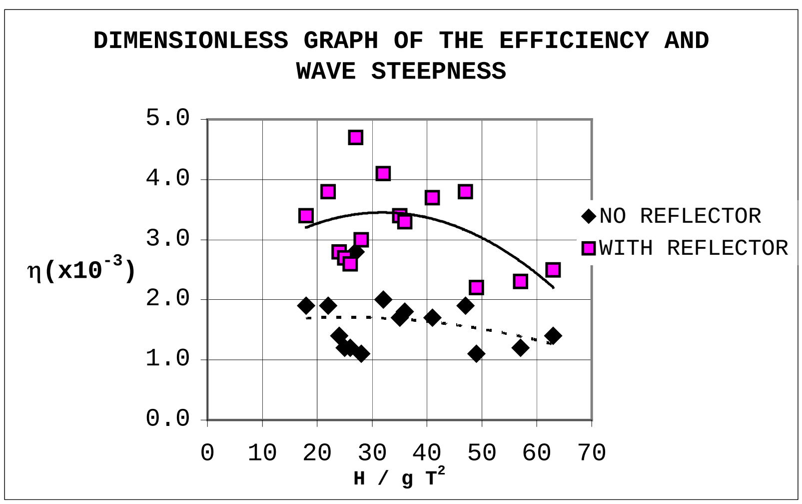


Figure 11: Dimensionless graph of the relation between efficiency and wave steepness

7.0 DISCUSSIONS

Effect of the changing wave period on the pressure as shown in Figures 6 through 8 shows that the increasing of wave period. The increasing of wave period causes the pressure through the orifice to increase by about 40%. Increasing wave heights significantly increase the pressure through the orifice. The increase in pressure was about 200%, as seen in Figures 8 and 9.

The immersion of the model or the water depth affected the pressure, where the water depth of 0.20 m produced better pressure. It means that immersion of the model is in the position of the top of the lateral entrance. The increase of the water depth above the lateral entrance causes the reducing of the pressure.

The effect of the changing of the reflector slope has been to increase the pressure. As can be seen in Figures 9-10, the model with reflector slope of 45^0 produced better efficiency compared to the remaining reflector slope. As can be seen from Figure 11 the efficiency for model with reflector is almost double than the efficiency of the model without reflector (previous experiment)

However, the experiment was rather imperfect due to the use of visual recording in this .experiment. Therefore, the author suggested that the experiment should be carried out in a larger flume tank in order a bigger model test can be used. A sensor like pressure transducer necessitates for the big model. The pressure transducer easily records the experiment due to the pressure transducer can directly connect to the computer.

8.0 CONCLUSIONS

The reflector applied in the OWC can improve the performance of the previous OWC (without reflector). The test conducted show that the efficiency of the OWC with reflector is better than the OWC without reflector. This feature can contribute to the consideration on the designing of the OWC. However, further works should be done to include the sensory devices via computer interface.

ACKNOWLEDGEMENT

The author is very grateful to the Domestic Collaborative Research Grant (DCRG) project of the Indonesian Higher Education Department for funding the research. The author is also grateful to The Inter University Centre, Gajah Mada University, Jogyakarta for hosting and supervising the experiment, especially to Prof. Dr. Nur Yuwono.

REFERENCES

1. Constant, J., (1979), *Marine Source of Energy*, Pergamon Press, New York.
2. McCormick, M.E., (1981), *Ocean Wave Energy Conversion*, John Wiley and Sons, New York.

3. Zheng, W. *Experimental Research and Parameter Optimization of a Prototype OWS Wave Power Devices,* Proceeding of the First International Conference of ICOER'89, American Society of Civil Engineering, New York.
4. Watanabe, K. *et. al.*, *Study on Pneumatic Wave Power Conversion System with the Water Valve Rectifier.* Proceeding of the International Conference of ICOER'89, American Society of Civil Engineering, New York.
5. Hiromoto, (1978), *A. The Theoretical Analysis of an Air Turbine Generating System*, Proceedings of Wave and Tidal Energy Symposium, Canterbury, England, paper 65.
6. Maeda, H., (1979), *Fundamental Research On Absorbing Energy From Ocean Wave*, Journal of the Society of Naval Architecture (JSNA), Japan Vol. 146, Dec.
7. Suroso, A., (1993), *Wave Energy Conversion System of Cavity Resonator Type for Indonesian Seawaters* (in Indonesia), Research Report, ITS Research Center.
8. Suroso, (1994), A., *Experimental Study of Wave Energy Conversion* (in Indonesia), Research Report, ITS Research Center.
9. Suroso, A., (1995), *Study of Air Pressure Phenomenon from the Orifice of Wave Energy Conversion System* (in Indonesia) Research Report of Starter Grant Project, The Indonesian Higher Education Department, Jakarta.
10. Suroso, A., (2000), *Experimental Study of Wave Energy Conversion System in Flume Tank* (in Indonesia)*,* Research Report, The Domestic Collaborative Research Grant (DCRG), The Indonesian Higher Education Department, Jakarta.