On the Hydrodynamics of Oscillating Water Column(OWC) of Wave Power Device

K. Thiruvenkatasamy* AND Michio Sato**

*Doctor course student, Department of Ocean Civil engg., Kagoshima University, 1-21-40, Korimoto, Kagoshima-shi, 890, Japan.
**Professor, Department of Ocean Civil Engineering, Kagoshima University, 1-21-40, Korimoto, Kagoshima-shi, 890, Japan.

1.Introduction:- The Oscillating Water Column(OWC) of wave power extracting caisson(Fig.1) might be subjected to severe impact of air pressure during hostile wave climate on closure of butterfly valve to safe guard the power module as well as during the incident waves of high steepness. Malmo and Reitan (1985) showed that there exists an excess pressure amplitude in relation to the incoming wave amplitude. The Amplification Ratio, (AR), which is the ratio of amplitude of oscillations inside OWC chamber to that of incident wave, is also maximum for an OWC in a reflecting wall when compared to other boundary conditions. The air compressibility effect is taken into account by the introduction of an effective turbine constant. Takahashi et al (1985) has reported that the results of model tests cannot be applied directly to the prototype on the basis of Froude similitude law due to difference in air compressibility between the model and prototype. This paper describes about the results of physical model tests on 1:50 scale model.

2.Theoretical model:- Takahashi et al.(1985) described the similitude law for the impact force in a chamber subjected to wave action. According to them, under fully closed condition of orifice, if the pressure on model is p_m and the prototype to model scale is 1:λ, then the prototype pressure p_p is not equal to $p_m \times \lambda$, but it is equal to $p_m \times \lambda \times (1/\varepsilon)$, where, ε is the adjustment factor which is a function of Bagnold number and model scale ratio. The Bagnold number for fully closed condition of given by,

$$B_g = 5\left(p_{ap}/p_0\right)^{\frac{2}{7}} + 2\left(p_{ap}/p_0\right)^{-\frac{5}{7}} - 7$$

where, p_{ap} = absolute pressure, p_o atmospheric pressure (1.01×10^5 N/m^2).

Fig. 2 shows the effect of Bagnold number (or) peak pressure on the adjustment factor for different model scales. Fig.3 shows the variation of pressure coefficient with relative water depth under fully closed condition of orifice(turbine duct). It is seen that the measured pressures scatter considerably which shows the extent of non-linearity of this problem. This confirms that fully closing of OWC orifice should be eliminated in order to avoid development of high pressures on the dome. An air pressure relief system could be the best option to eliminate this excess pressure. As discussed earlier, the adjustment factor should be appropriately considered in order to take care of compressibility effect if prototype pressure value needs to be estimated. For the present study, the range of Bagnold number is from 0.0 to 0.00042 and the corresponding range of p_p/p_0 is from 0.0 to 0.0238 (where, p_p is the measured peak gauge pressure). With this model scale of 1:50, the anticipated adjustment factor is about 6.0. This needs further investigation, since the plot shown in Fig. 2. is for caisson without harbour. Numerical study on effect of air compressibility inside OWC is in progress.

3. Water Surface Oscillations inside OWC:-Water surface oscillations inside OWC chamber is needed to select the height of the OWC chamber in order to avoid excess impact from oscillating water mass; it is carried out by using a parameter called " Amplification Ratio (AR)" which is defined as:

Amplification Ratio (AR) = $\pm\left(a_{OWC}/a_i\right)$; In general, it is observed that, the AR decreases with increasing wave frequencies for all the conditions studied. The present study shows that the positive AR is more than the negative AR for all the conditions studied. A overall study shows that the height of OWC chamber above SWL would be six times the amplitude of incident wave, if the impact of oscillating water mass is to be completely eliminated.

4.Conclusions

a) For 1:50 model, the average measured peak gauge pressure is 1202.9 N/m^2. The corresponding anticipated adjustment factor is 6.0. The observed maximum pressure is 8.0 times the static pressure of incident wave amplitude.

b) The amplification ratio(AR) decreases with increasing frequencies for all the conditions studied. The positive AR attains a maximum of 6.0.; The rate of decrease of AR value with increasing frequency increases significantly from fully closed to fully opened condition of turbine duct which is probably due to the more air outflow through orifice.

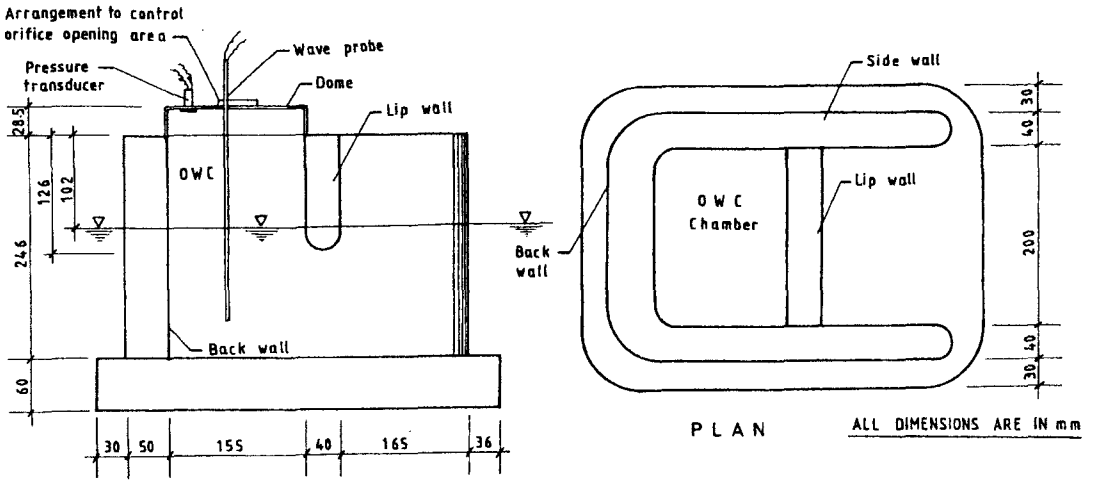

Fig.1. OWC Model

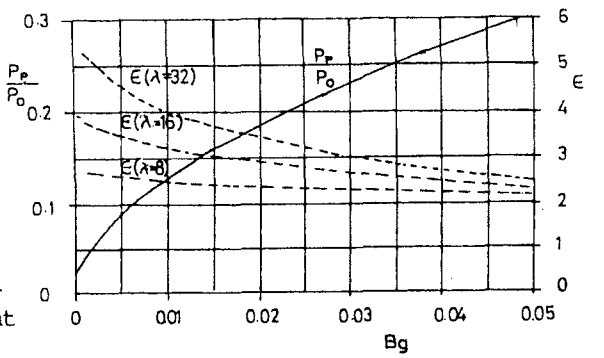

Fig.2. Effect of Bagnold Number (or) peak pressure on Adjustment factor(ϵ) for duct(closed)

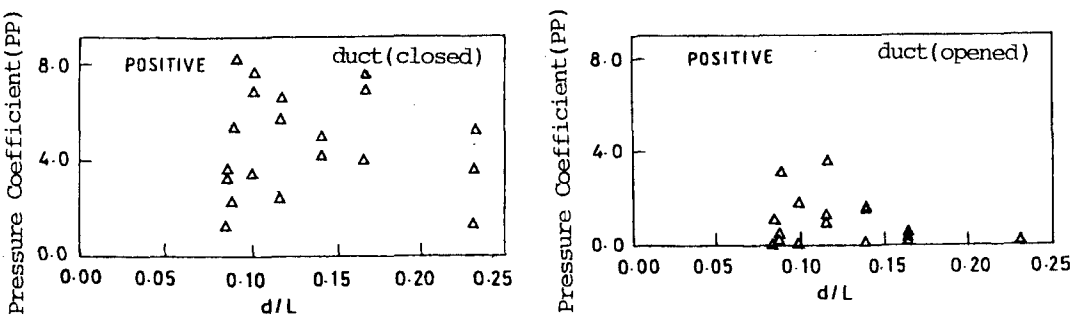

Fig.3. Effect of wave frequency on Pressure Coefficient(pp)