"PRAMETRIC MODELLING OF "PENDULOR" TYPE WAVE ENERGY CONVERTER

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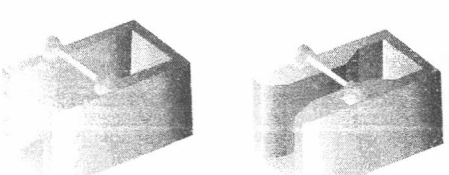
Introduction

The "Pendulor" device is used to extract ocean wave energy by using a hinged flap in a caisson. The ocean waves excites the oscillatory moment of the pendulum flap. The device which was originally invented in Japan used a hydraulic vane-pump at the hinge point of the flap as the power takeoff system at a constant pressure (Fig 1). The horizontal water particle motion excites the excitation moment on the pendulum. The caisson length is a major factor on the construction cost. With the conventional straight caisson, the caisson length would be about 25m.

The caisson length reduction and broadening the operating frequency bandwidth are the major objectives of introducing a modified caisson (fig 2). Mathematical model is available for the original system with the straight caisson (A.Ando et al, 1984).



(a) (b)

Fig.2. Caisson configurations, (a) - conventional caisson, (b) - modified caisson

In the previous studies a modified caisson was proposed to shorten the caisson length and to increase the operating frequency bandwidth (Gunawardane et al, 2009).

An Analytical modeling of the modified caisson is complex because of the shape of the caisson. Therefore, an experimental method was used to analyze the effect of caisson configuration on the Pendulor device.

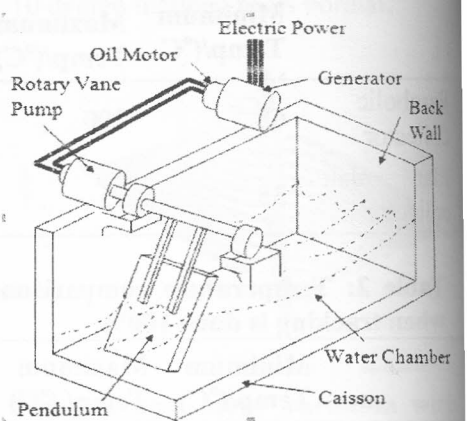


Fig. 1 Basic pendulum device

Mathematical model

The governing equation of the Pendulor device with mechanical friction brake shown in Figure 3 can be written as (Tomiji Watabe)

$$\sum I\ddot{\theta} + (N_h)\dot{\theta} + N_m + \sum K\theta = M_0 \sin \omega t$$

$$\sum I = I_h + I_m, \quad \sum K = K_h + K_m$$

I_m: Moment of inertia of the pendulum,

I_h: Moment of inertia of the added water mass, N_m: Mechanical friction damping factor, N_h: Hydrodynamic damping factor, K_m: Coefficient of restoring moment by the pendulum due to gravitation, K_h: Coefficient of restoring moment by the water mass elevation behind the flap,
Mo: Amplitude of wave excitation moment.

Methodology

In the above governing equation, I_h, N_h, Kh cannot be calculated by analytical methods by finding velocity potentials of the respective zones inside the caisson due to the complex shape of the caisson. Therefore, parametric modeling method was used to estimate the unknown parameters least square method (minimizing the error). As the starting value of those parameters in the parametric modeling program, the corresponding values in straight caisson were taken. The moment of inertia of the pendulum was calculated with the physical dimensions of flap and the mechanical damping torque was set to a known value with the friction damper.

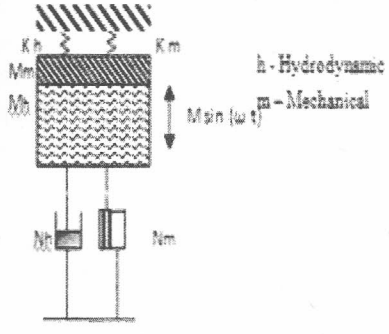


Fig .3 Mathematical model of pendulor device, (with constant friction damper)

Experimental set up

Experiments were carried out in a 2D wave channel shown in Figure 4 of 10 m in length for 1/16 scaled model of a proposed 250 kW power plant (Watabe et al, 2001). Incident waves were measured by using a wave gauge and the amplitude of flap oscillations were measured by an encoder. Wave gauge signals and encoder signals were recorded in a computer. Data were collected only for initial about six cycles of the wave in order to avoid nonlinearity in the wave due to mixing of reflected and incident waves. A friction brake system was used as the power take off system

Results and Discussion

The output of the system (pendulum oscillation) was measured with the time. The difference between the measured output and the modeled output was minimized in order to find the optimum parameter values of the mathematical model. Figure 5 shows one example on the above optimization for real time response. Based on that modeling, the important parameter that governs the power extraction of the system M_0 was observed. Figure 6 shows the variation of the excitation moment with the wave circular frequency. There is no significant variation in the excitation moment *Mo* within the available data range.

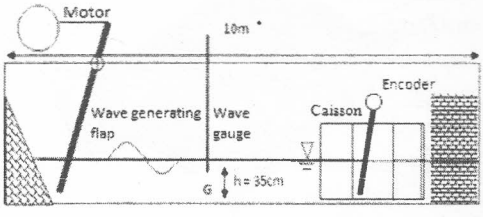


Fig .4. The experimental set

The device efficiency variation with the damping torque and the wave frequency was also investigated by the experimental results (Figure 7). It was observed that the maximum efficiency reaches about 70% at the damping torque of 6 Nm and 1.35 Hz frequency.

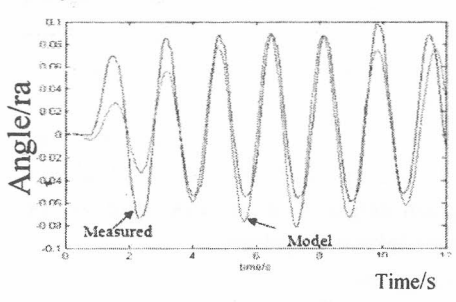


Fig. 5 – modeled output values and the measured output values.

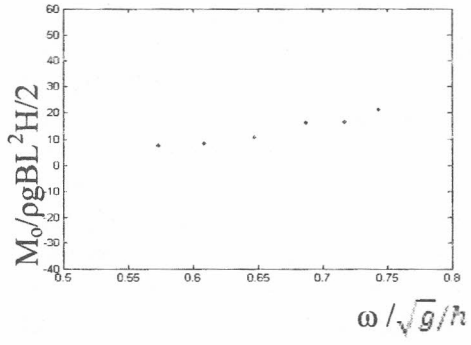


Fig. 6. variation of non dimensional excitation moment with frequency

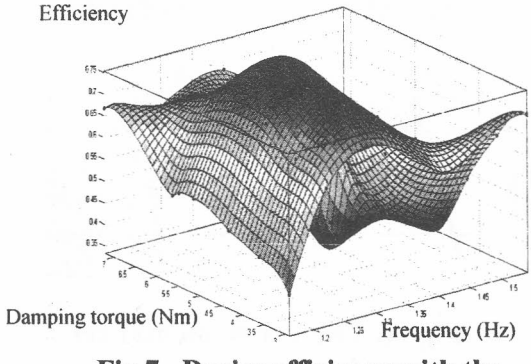


Fig.7. Device efficiency with the frequency and damping torque

References

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