Study of the effects of opening ratio of airflow control valve on the dual duct OWC chamber system

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***Abstract*— This paper deal with the investigation of the effects of opening ratio of airflow control valve for dual duct OWC chamber system. The system contains OWC chamber and dual duct. One duct is used for installing the energy-converting device and other one is for control the flow rate using flow control valve. The performance of energy converting device can represented by the free surface elevation inside the chamber and bi-directional air velocity in the duct. The airflow control valve is use to control the air velocity against the difference proposed site incident wave conditions. The effects of opening ratio of control valve at the flow control duct have investigated using experimental methods. The wave elevation inside the chamber, the pressure difference and air velocities in the both of duct have measured to predict the pneumatic power of OWC system. A relationship between opening ratio of flow control valve and airflow rate has investigated in the dual duct OWC system.**

***Keywords*— OWC, Dual duct, Airflow control valve, Experiment, Air velocity, Wave elevation**

I. INTRODUCTION

Among the various type of wave energy converter, the OWC type is the most wildly used device because of the benefit of the easy maintenance. The main advantage of the OWC versus most other WECs is its simplicity. The only moving part of the energy conversion mechanism is the rotor of a turbine, located above water level, rotating at a relatively high velocity and directly driving a conventional electrical generator. Because of these advantages, the OWCs are the major class of wave energy converter, which the largest of number of prototypes so far deployed into the sea [1].

Many studies for optimizing the shapes of OWC chambers are performed by both experimental and numerical study. The major design parameters of the OWC chamber are length, width and depth of the skirt. The results show that the ratio of incident wave periods and chamber length are significant parameter for OWC chamber. The decreasing depth of skirt will increase the performance of OWC chamber but there is limit have to deeper than amplitude of incident wave [2]. In order to improve the efficiency of first energy converting device, several new configurations of OWC chamber are proposed. A novel OWC chamber with a small vertical U-shape duct differing from traditional air chamber is introduced. An analytical description has presented and solved by Monte Carlo simulations to investigate the influence of turbines and other shape parameters [3]. A projecting wall is proposed to improve the performance of wave energy converter. From the calculation, the length of the projecting wall is show to affect the efficiency of primary conversion [4].

Most studies always focused on the single phase ignoring effects from the other process. Liu et al. predicted the OWC air chamber performance under impulse turbine damping effects. Orifice plate has used as the pressure drop substitute, which is validated in the experimental and numerical wave simulator. Two-phase VOF model based 3D numerical wave tank is established using commercial CFD code Fluent, capable of predicting airflow and pressure variation. The orifice plate was installed in the dual-duct system on the chamber. Water surface elevations, air flow velocity and pressure variation inside the chamber are simulated numerically, which are validated by corresponding experimental data. Operating performance of air chamber for Yongsoo OWC pilot plant installed with 0.43D orifice as the pressure drop substitute of the designed impulse turbine are computed. The results show that the turbine damping effects will cause around 30% reduction in the peak values of the pneumatic energy output of the OWC air chamber in the resonant wave domain [5, 6].

This paper investigated the effects of opening ratio of airflow control valve on the air flowrate varies in the dual duct using experimental method. The results of this research can applied to the operating of real sea test site for air turbine. Through control the opening ratio of valve, the incident energy which driving turbine to generator power can control to test the air turbine system. The experiment carried out in the 2-D wave tank, which is 30m in length, 0.6m and 0.6m in depth and width. The orifice plate is installed in the duct for considering the turbine effects, the butterfly valve is used to control the airflow rate in the duct. The wave elevations in the chamber and the velocities in the two ducts are measured in the experiment. A relationship between opening ratio of flow control valve and airflow rate is investigated in the dual duct OWC system.

II. EXPERIMENTAL SETUP

A. *Experimental facilities and test model*

The experiment was carried out in 2-D wave flume at the KRISO in KOREA. The dimension of wave flume is 30m, 0.6m and 0.6m in length, width and depth, respectively. The active wave making system was applied in the flume. The facility can generate incident maximum wave height at 15cm, and maximum period at 2.4s.

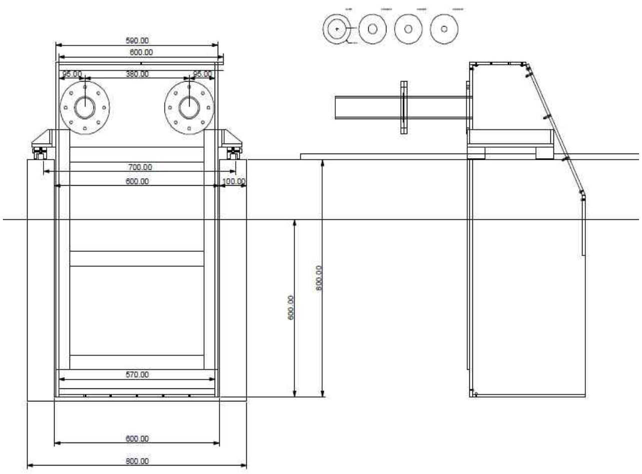

Fig. 1 Configuration of OWC chamber model (side view, end view)

Fig. 2 Experimental setup

The model is composed of Polycarbonate material and its thickness is 10T, and the configurations of model show in Fig. 1. The still water depth is 0.6m, and the width is 0.57m while the chamber roof length at 0.195m. The length of chamber is 0.4m, depth of skirt is 0.2m and the height of chamber is 1.13m. The duct diameter is 0.08m with 0.8m length. The orifice and butterfly valve installed in each duct. The test model has installed in the flume 20m away from wave making system. The Fig. 2 shows the 2-D wave flume and experimental setup.

B. Data acquisition system and experimental conditions

The capacitance type wave gauge has used for measuring the incident wave and wave elevations in the chamber. The hotwire velocity gauge has used for measuring the airflow rate in the airflow control duct and energy converting duct. The velocities are measured at the point of mid-section of orifice and valve to chamber. The pressure is measured at the same point with velocity also. Additionally, the pressure of inside chamber is measured. All the experimental data are collected by NI USB-6363 DAQ system.

The experiments performed in the condition of regular wave. The incident wave heights are 0.036m and 0.072m while in the same wave period conditions. Two kinds of orifice are selected to investigate the difference of turbine effects such as 0.3D and 0.4D. The opening ratios of butterfly valve are varied from 0% to 100%. The wave elevation in the chamber, the velocities and pressure in the ducts are measured at the different opening ratio of valve.

TABLE I
EXPERIMENTAL CONDITIONS

H	T	Orifice	Opening ratio
0.036m	0.8~2.0s	0.3D, 0.4D	0~100%
0.072m	0.8~2.0s	0.3D, 0.4D	0~100%

III. EXPERIMENT RESULTS

A. Time history of measuring data

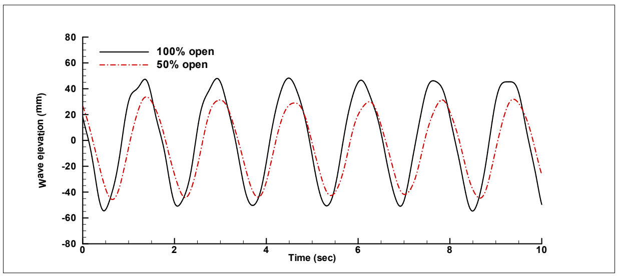

Fig. 3 Wave elevation inside chamber

The wave elevations inside chamber show in Fig. 3. A 0.4D orifice is installed in the duct, and the incident wave condition is 0.072m in height and 1.6sec in period. The effects of opening ratio of airflow control valve show in this figure. It can found that the wave elevation of opening ratio at 50% has decreased more than 10% comparing with the case of fully open. It can consider like a nozzle effects, the damping force blocked the water surface moving.

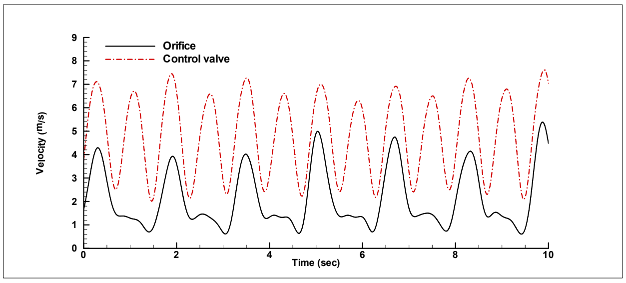

Fig. 4 Time history of air velocity in the duct (100% open)

The time history of air velocities in the duct shows in Fig. 4 and 5. Fig. 4 shows the results of case at the fully open, and the Fig. 5 shows the case of 50% open. Air velocity in the orifice duct is smaller than the velocity in the airflow control duct at the case of fully open. On the other hand, the velocity of airflow control duct is smaller than orifice duct. Because of the measuring point, the velocity in the exhaust process is smaller than inhalation in the orifice duct. While, the velocity in the airflow control duct shows different trend. In the fully open case, the velocity at the inhalation process is larger than exhaust process, but in the 50% open case the trend shows vice versa.

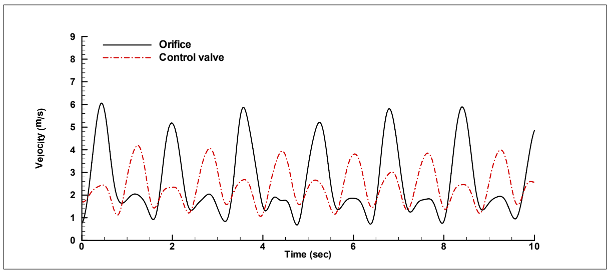

Fig. 5 Time history of air velocity in the duct (50% open)

B. Effects of opening ratio

The effects of opening ratio of flowrate control valve in the relative wave height inside chamber show in Fig. 6. According to wave period increasing, the relative wave heights inside chamber show increasing too except in the case of 1.6 sec. In the case of 75% open cases, the relative wave height show similar with 100% open cases. It seemed that the characteristics of butterfly valve cause that phenomenon.

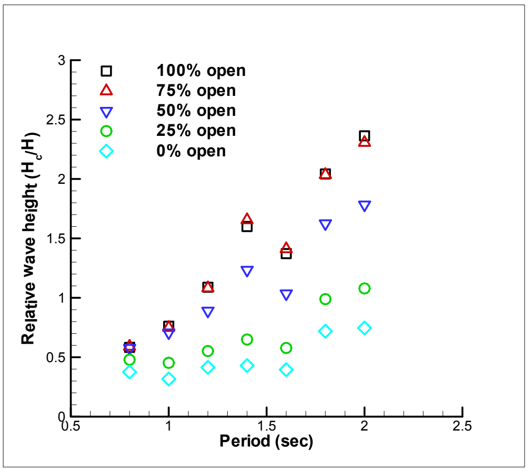

Fig. 6 Relative wave height in chamber

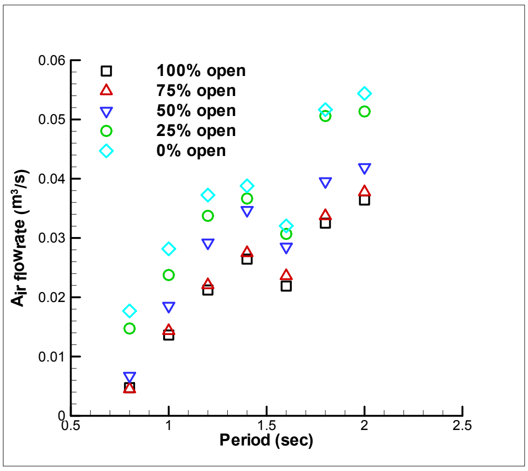

Fig. 7 Air flowrate in the orifice duct

According to the opening ratio, variations of the air flowrate in the orifice duct show in Fig. 7. The orifice has installed to replace the turbine, so the air flowrate in the orifice duct is the incident energy of turbine system. In the case of 75% and 25% open, the flowrate variations are not significant comparing with the adjacent cases. The characteristics of butterfly valve seemed in air flowrate also.

C. Effects of orifice and valve

The comparison of air flowrate in the orifice duct and the valve duct show in Fig. 8. The purpose of the flowrate control valve is to control the air flowrate to the turbine system through the opening ratio of valve. The total air flowrate of dual duct are not equal to each case in the same incident wave conditions. The different opening ratio causes the different pressure inside chamber, than the pressure will block the water surface elevating. Therefore, the total amount of the air flowrate will varies.

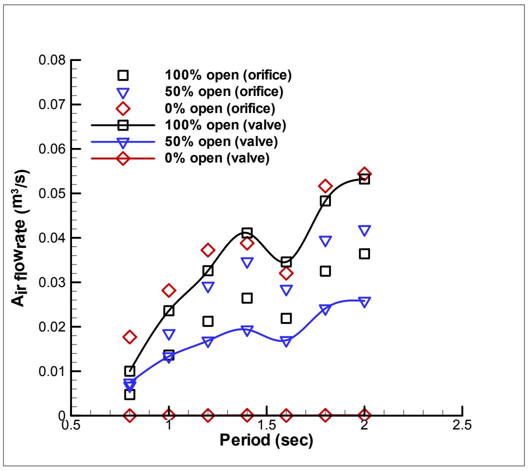

Fig. 8 Air flowrate comparison between orifice and valve duct

IV. CONCLUSIONS

The investigation of the effects of opening ratio of airflow control valve for dual duct OWC chamber system are presented in this research by experimental method. The experiment had carried out in the 2-D wave flume located in KRISO. For consider the turbine effects the orifice was used in the turbine system duct. A butterfly valve was used to control the air flowrate in the duct through changing the opening ratio of valve. The wave elevations inside chamber and air velocities in the duct are investigated in the condition of different valve opening ratio.

The effects of opening ratio of flowrate control valve in the relative wave height inside chamber show that according to wave period increasing, the relative wave heights inside chamber show increasing too except in the case of 1.6 sec. In the case of 75% open cases, the relative wave height show similar with 100% open cases. Variations of the air flowrate in the orifice duct show that in the case of 75% and 25% open, the flowrate variations are not significant comparing with the adjacent cases. The characteristics of butterfly valve seemed in the relative wave height and air flowrate.

The comparison of air flowrate in the orifice duct and the valve duct show that the total air flowrate of dual duct are not equal to each case in the same incident wave conditions. The different pressure inside chamber will block the water surface elevating. Therefore, the total amount of the air flowrate will varies. The relationship between the control-valve opening ratio and air flowrate in the turbine system duct will investigate in the future.

ACKNOWLEDGMENT

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