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Numerical Methods to Predict Characteristics of Oscillating Water Column for Terminator-type Wave Energy Converter

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Two numerical methods are described for analyzing a terminator-type wave energy conversion device under the condition that the linear water wave theory is applicable. Two methods are proposed to calculate the device characteristics of an oscillating water column (OWC) type. One uses the flow rate and gauge pressure in the air chamber directly, because in this system the interaction between the OWC and the turbine is found to be controlled only by the flow rate and the pressure drop through the turbine. The other method uses the equation of the floating body motion in a manner similar to the equivalent floating body approximation. The relations between these methods are also examined. The hydrodynamic performance with frequency from zero to infinity is required in the simulation of irregular waves. However, resonance occurs when the air chamber breadth is nearly equal to multiples of half a wavelength. The impulse response function is then modified in order to eliminate the effects of the resonance frequency. Finally, it is confirmed that these solutions give good agreement with the experimental results.

NOMENCLATURE

a	amplitude of incident wave
A_W	water surface area in air chamber (OWC) $= BW$
B	breadth of air chamber
c	hydrostatic restoring force coefficient $= \rho g A_W$
d	front wall submergence depth on OWC
D, D_p	load damping coefficient of OWC ($D = D_p A_W$)
$f(k_0 h)$	$2\cosh^2(k_0 h)/(2k_0 h + \sinh(2k_0 h))$
g	gravitational acceleration
h	water depth
H	wave height
k	wave number
K	wave number at infinite water depth $= \omega^2/g$
$K(t)$	unit impulse response function depending on heaving velocity
$K_p(t)$	unit impulse response function depending on pressure
m_a	added mass
N	wave damping coefficient or number of terms
$p(x, z)$	complex pressure
$P(x, z, t)$	$p(x, z)e^{i\omega t}$
R	opening ratio of orifice (or air chamber)
t	time
U	x component of complex velocity
V	z component of complex velocity
W	width of air chamber
W_i	incident regular wave power
W_{OWC}	output of OWC in regular water wave
ε	wave excitation coefficient
$\phi(x, z)$	complex velocity potential
$\Phi(x, z, t)$	$\phi(x, z)e^{i\omega t}$
η	efficiency (or capture-width ratio) of OWC for regular wave
ρ	water density
ω	angular frequency

Superscripts

$*$	conjugate complex number
$\cdot$	d/dt
$\cdot\cdot$	d^2/dt^2

Subscripts

I	domain I
II	domain II

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INTRODUCTION

A wave power generating system of the oscillating water column (OWC) type is composed of a turbine generator and an air chamber in which the OWC converts wave energy into an oscillating airflow (Raghunathan, 1995; Washio et al., 2000). A Wells-type turbine is used for the air turbine because it is suitable for the operation in an oscillating airflow. The Wells turbine will always rotate in the same direction irrespective of the direction of the oscillating airflow. Further, the Wells turbine has a simple configuration and structure. This is why it is very commonly used for the conversion of wave energy. The Wells turbine has a special characteristic for the OWC: A linear pressure drop over the blade against the flow rate under constant rotational speed, that is, the load damping coefficient of OWC has linear characteristics (Suzuki et al., 2000).

The numerical methods for analyzing a wave energy conversion device of the OWC type are described under the condition that