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振動水柱型 波力發展의 吸水波力 推定에 關한 硏究

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The Estimation for Extracted Wave Power of Ocean Wave Energy Conversion Device of the Oscillating Water Column Type

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요 약

본 논문에서는 단위 폭당 입사파의 파력틀 자유표면의 일정지역에 작용하는 파력으로 다루었고, 파력발전의 유체력 추정은 3차원특이점분포법을 이용하였다. 특히, 수주안의 유체 유동을 추정하기 위하여 수주안의 유체 상부에 얇고 가벼운 박판이 존재하는 것을 가정하였다. 이러한 박판에 Source(특이점)를 분포시키고, 이로부터 이 박판의 거동을 추정하여, 이 박판의 거동과 수주안의 유체유동이 일치될 것으로 가정하였다. 이 방법은, 특히, 수주안의 유체유동과 수주, 각 수주간의 간섭효과를 고려할 수 있으며, 실제 상황에서도 수주안 유체유동의 균일화, 유체입자의 분산방지, 등의 장점을 예상할 수 있다. 또한, 수주내 변동압력을 고려하여 Source를 2가지 방법으로 분포시켜 계산을 수행하였다.

파력발전의 수주내의 흡수파력은 얻어진 수주내 파고 분포를 이용하여 수주내 자유표면 근처의 공기 압력을 계산하고, 이러한 공기 압력이 Orifice단면을 통과하는 과정에서의 에너지 손실을 고려하여 추정하였다.

Abstract

The estimations of absorption powers for a large wave energy conversion devices of floating type in ocean have not been achieved the desired results due to the structural complexity and the mutual interference of "water columns".

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Thus, in this paper the author will propose a new methodology based on the three dimensional source ditribution method. It is the method that this is distributed the source for the thin and light plate in "water column" and from the behaviour of this, calculated the power and the pressure in water column. But, yet this numerical method will be proved to be valid by experiment.

1. Introduction

The study for the wave energy conversion is not only necessary to the development of the substitution energy but also the efficient utilization of the ocean space.1),2) Nevertherless, the estimations of absorption powers for a large wave energy conversion devices of floating type in ocean have not been achieved the desired results due to the structural complexity, the mutual interference of "water columns", etc. Especially, due to a problem of transmission from the ocean to the land, of irregular productive capacity, etc, it is placed in difficult circumstances. But we are thought that the efficient device may be obtained through continuous study.2),3)

In this paper, designed model is used to U03 which is to have the multiple oscillating "water column" in freesurface. The wave powers of incident wave are calculated in consideration of a relevant area of freesurface.4),5) The three dimensional source distribution method is used to estimate the hydrodynamic forces on a wave energy conversion device and to calculate the hydrodynamic forces according to the variations in length and direction of incident waves.3),5),6) In order to estimate the behaviour of water in water column, we assumed that it is the thin and light plate in water column. It is ditributed the source below this plates and calculated the behaviour of this. And we assumed that it identified the behaviour of this with the water flow in water column. It is able to be considered the interference effects of water column and water flow and of each water columns. Somewhat, the distribution of source in this plates made choice of two methods out of consideration for the fluctuation pressure in water column.7),8)

Using the distribution of the wave height in water columns to be obtained by that process, it is calculated the air powers of a neighbourhood on freesurface in this. The extracted wave powers are estimated in consideration of a loss of a energy in the process of air flow from freesurface to orifice area. And, the air pressures through out the orifices are estimated in consideration of a vertical velocity of water paticles in water column.

2. The Wave Power of Incident Wave

The linear wave power influences the OWC device according to the variation of wave length is as fllowing.

$$P_r = 0.0012258\rho_w g H^2 C_g B/(\lambda/L)\,(K_W) \qquad (1)$$

where, ρ_w : Water dencity (102Kgf sec^2/m^4),
H : Height of incident wave(m),
C_g : Group velocity of incident wave (m/sec),
λ : Length of incident wave(m),
B : Breath of the OWC device (m),
L : Length of the OWC device(m). (1)

3. The Extracted Wave Power of OWC Device

The three dimensional source distribution method is used to estimate the hydrodynamic forces on a wave energy conversion device and to calculate the hydrodynamic forces according to the variation in length and direction of incident waves. In order to estimate the behaviour of water in water column, we assumed that it is the thin and light plate in water column. It is ditributed the source below this plates and calculated the behaviour of this. And we assumed that it identified the behaviour of this with the water flow in water column.

It is assumed that it is able to fall the level of inner water by the fluctuation pressure in water column. The level of inner water is calculated by reference[7].

Using the distribution of the wave height (ζ) in water columns, the wave powers (P_c) of fluid in these calculated as following.

$$P_c = P_r \times \zeta^2/H^2 \times b/(L\times B)\,(K_W) \qquad (2)$$

where, l : Length of water column (m).
b : Breath of water column (m).

From the consideration of the relation between water dencity and air dencity, the air powers (P_{cs}) of a neighbourhood on freesurface in this calculated as following.

$$P_{cs} = P_c \times \rho_w/\rho_a \qquad (3)$$

where, ρ_a : Air dencity (0.125Kgf sec^2/m^4).

Because of a variation of a power in the process of air flow from freesurface to orifice area(namely, a area type of a water column, orifice area and a “side flow” coefficient of orifice), the extracted wave powers per orifice area(CP_{co}) are estimated as following.

$$CP_{co} = 1/A_o \times C_m \times C_o \times P_{cs}\,(K_W/m^2) \qquad (4)$$

where, A_o : Area of orifice(m^2),
C_m : Coefficient of area type in water column (0.8),
C_o : "side flow" coefficient of orifice (0.65).

4. The Air Pressure in Orifice

From the relation between a vertical velocity (V_z) of water paticles in water column and a area of water column, the fluctuation flux is as follows.

$$Q_w = A_c \times V_z \tag{5}$$

$$A_w \pi \times \zeta / T_w \times e^{k \times z} \times \sin(\theta)$$

where, T_w : Period of incident wave (sec)
K : Wave number of incident wave
Z : Wave crest ($=\zeta/2$)
θ : X-position of incident wave direction

The fluctuation flux of air through out the orifice is as follows.

$$Q_o = C_o \times A_o \times \sqrt{P(t) \times g/\rho a} \tag{6}$$

where, P(t) : Fluctuation pressure of air in orifice (Kg/m^2)

As it is identified the fluctuation flux of water with the fluctuation flux of air, the fluctuation pressures of air thrrough out the orifices are estimated as following.

$$P(t) = \frac{\rho_a}{g} \times \left(\frac{A_c}{C_o A_o} \right)^2 \times \left(\frac{\pi \zeta}{T_w} \times e^{k \times z} \right)^2 \frac{1}{2\pi} \int_{-\pi}^{\pi} \sin^2\theta d\theta \quad (Kg/m^2) \tag{7}$$

5. Simulation and Consideration

The three dimensional source distribution method is used to estimate the hydodynamic forces and the water height in water column. The principal dimmension of U03 is presented in Table 1. A source on U03 OWC device is distributed 214 number. It is disregarded the thickness of vertical plate. And the source is distributed both sides of vertical plate. This method is able to be considered the interference effects of water column and water flow, of each water columns.

Fig 1. 1 shows the amplitued and path of heave motion according to the variation of incident wave direction and length. It is shown many variation in $\lambda/L=1.0$

Fig 2-1. 2-1 and Fig.2-2 show the distribution of wave height in each water columns in case of

Table 1. Principal Dimension of U03

		U03 Type (M)	Comp.
Length (L)		1.0	
Breath (B)		0.45	
Depth (D)		0.25	
Draft (T)		0.15	
Center of Gravity	V.C.G.	0.05	
	L.C.G.	0.00	
	T.C.G.	0.00	
Water Depth		∞	
Design Wave Height		0.05	
Design Wave Length		1.00	
Waterline Area Ac		0.03275	
Air Chamber	Total Num.	30	U03=26
	∇a (m³)	0.15×10^{-2}	0.00135
	Ac (m²)	0.15×10^{-1}	0.01354
	Aa (m²)	0.75×10^{-4}	$\beta=1/200$

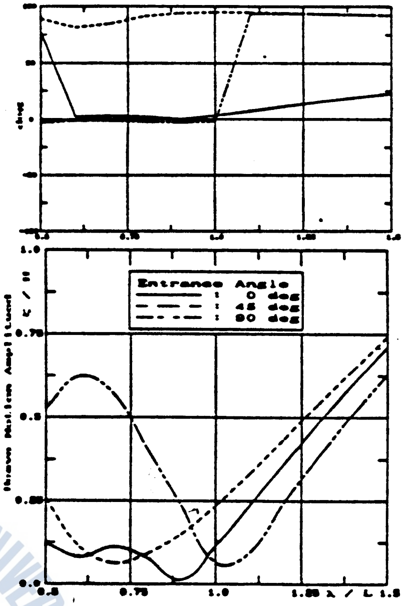
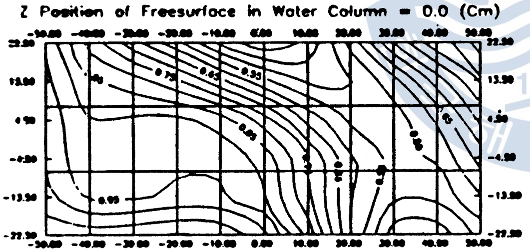


Fig 1. Amplitude & Path of Heave Motion for U03



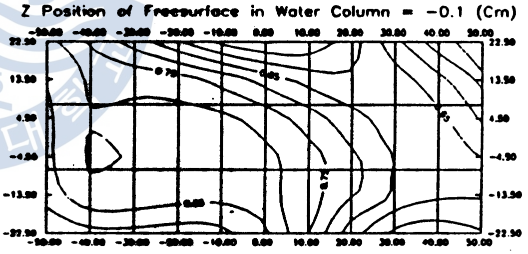


Fig 2-1. Distribution of a Fluid Amplitude in Water Column. (by Non-consideration of Inner Pressure)

Fig 2-2. Distribution of a Fulid Amplitude in Water Column. (by Consideration of Inner Pressure)

$\lambda/L=0.7$ and incident wave direction=45 deg. Fig. 2-2. shows the distribution in case of Z position of freesurface in water column=−0.1cm. We can see greater wave height in Fig. 2-1 than Fig. 2-2.

Fig 3. shows the absorption ratio for wave power according to the variation of incident wave direction and length. In comparison with Fig. 1, we are known that the absorption ratio is not in inverse proportion to the amplitued of heave motion and lower than 10%.

Fig 4-1. Fig. 4-2 and Fig. 4-3 show the distribution of air power through out the orifice area. In case of short wave, we can see that it is lower the absorption ratio but higher the absorption capacity. This results are obtained from the equation(4).

Table 2-1. Table 2-2 and Table 2-3 show the distribution of air pressure through out the orifice

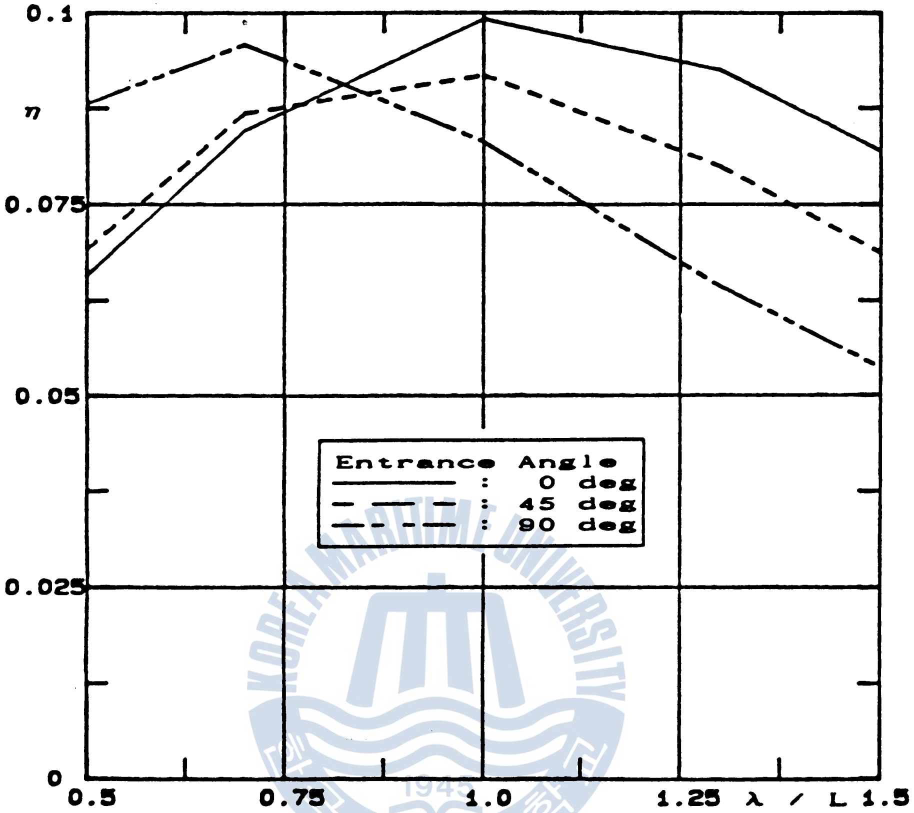


Fig 3. Average Absorption Ratios for Wave Power in U03.

area. This results are obtained from the equation (7). Table 2-1 shows the greatest value in the center of the OWC device. From Table 2-2 and Table 2-3, we can see that the region of stem is calculated lower the absorption pressure than the region of stern.

6. Conclusions

From this study, it is obtained the result as following.

(1) It can be known that the absorption ratio is not in inverse proportion to the amplitued of heave motion.

(2) In case of short wave, it can see that it is lower the absorption ratio but higher the absorption capacity.

(3) It can see that the region of stem is calculated lower the absorption pressure than the region of stern.

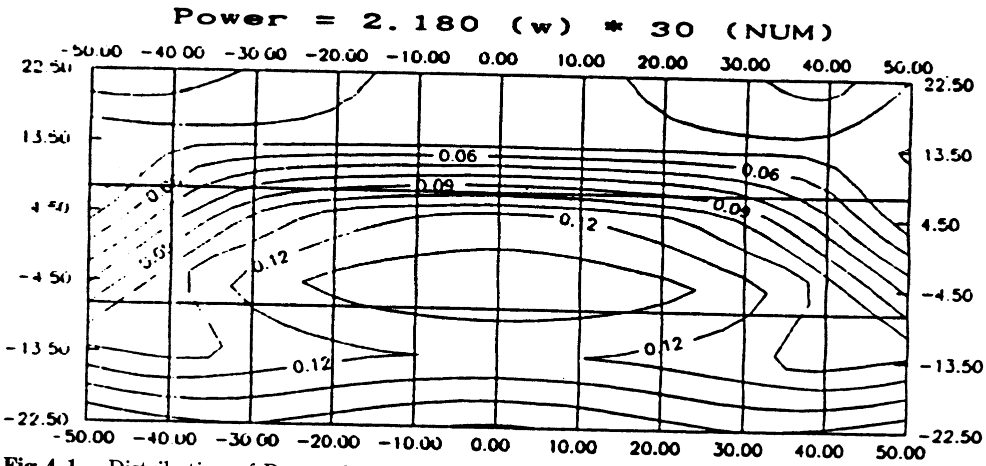


Fig 4–1. Distribution of Power through out orifices. (λ/L=0.7 Incident Wave Direction=90°)

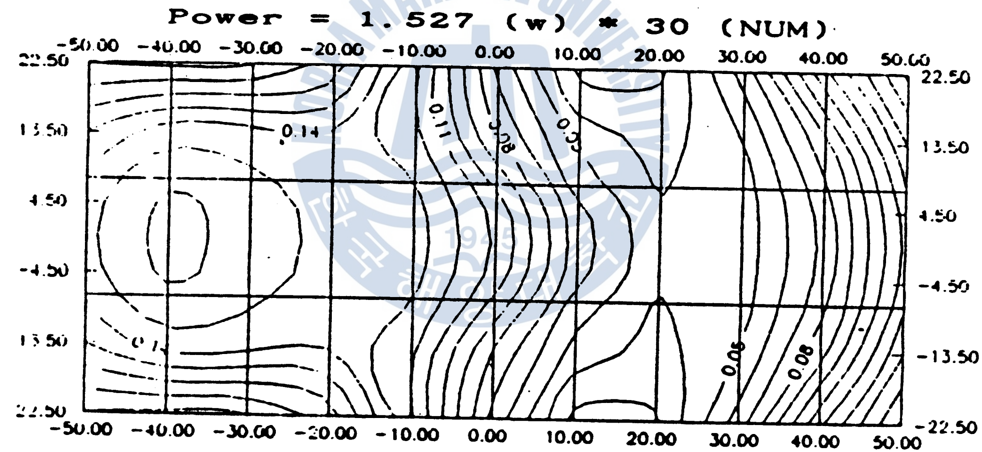


Fig 4–2. Distribution of Power through out orifices. (λ/L=1.0 Incident Wave Direction=0°)

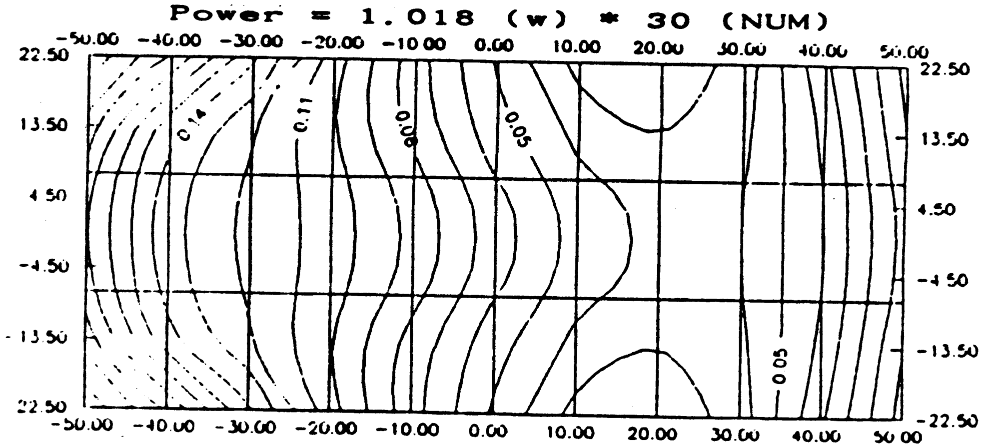


Fig 4–3. Distribution of Power through out orifices. (λ/L=1.5 Incident Wave Direction=0°)

Table 2-1. Distribution of Pressure through out orifices
($\lambda/L=0.7$ Incident Wave Direction$=90°$)

$T_w=0.66992E+00$(sec) K$=0.89760E+01$ (10^{-4}Kg/Cm^2)

(137)	(145)	(144)	(142)	(140)	(140)	(142)	(144)	(145)	(137)
(208)	(320)	(384)	(415)	(429)	(429)	(415)	(384)	(320)	(208)
(372)	(372)	(392)	(409)	(419)	(419)	(409)	(392)	(372)	(372)

Table 2-2. Distribution of Pressure through out orifices
($\lambda/L=1.0$ Incident Wave Direction$=0°$)

$T_w=0.80071E+00$ K$=0.62832E+01$ (10^{-4}Kg/Cm^2)

(305)	(293)	(299)	(278)	(197)	(101)	(59)	(71)	(131)	(212)
(244)	(233)	(258)	(274)	(245)	(158)	(88)	(71)	(101)	(190)
(305)	(293)	(299)	(278)	(197)	(101)	(59)	(71)	(131)	(212)

Table 2-3. Distribution of Pressure through out orifices
($\lambda/L=1.5$ Incident Wave Direction$=0°$)

$T_w=0.98067E+00$ K$=0.41888E+1$ (10^{-4}Kg/Cm^2)

(215)	(168)	(137)	(104)	(74)	(48)	(32)	(33)	(53)	(98)
(186)	(149)	(133)	(113)	(86)	(61)	(44)	(40)	(53)	(90)
(215)	(168)	(137)	(104)	(74)	(48)	(32)	(33)	(53)	(98)

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