DYNAMICS OF THE FLOAT-COUNTERWEIGHT WAVE ENERGY CONVERTER WITH THE APPLICATION OF TENSION PULLEY

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1. INTRODUCTION

In this paper the application of tension pulley to suppress the occurrence of negative tensile forces in the suspension cable and flatten the output power of the float counterweight wave energy converter[1], shown in Fig. 1, is investigated. As shown in Fig. 2, the tension pulley, a combination of a spring and a pulley, is located between the driving pulley and the idler pulley on the float side and maintains tension in the suspension cable and prevents it from slackening when the tension generated by the weight of the counterweight is not large enough.

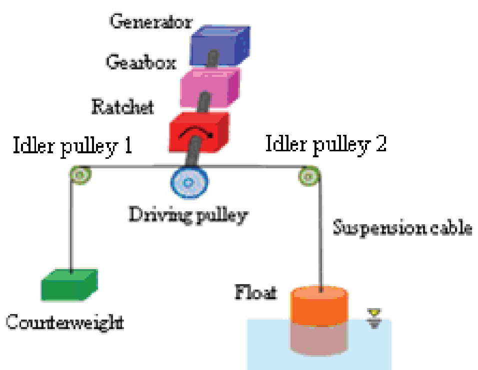

Fig. 1 Schematic diagram of the energy converter

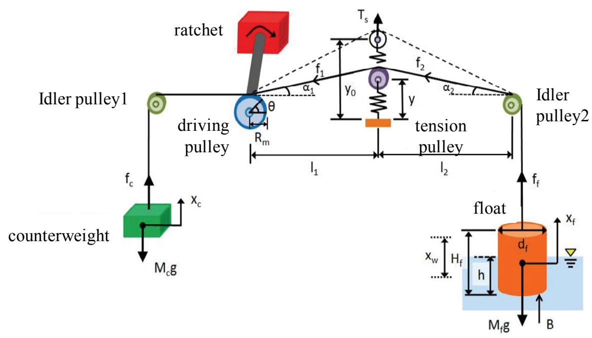

Fig. 2 Schematic diagram of the energy converter with the application of tension pulley

2. DYNAMICS OF THE ENERGY CONVERTER CONSIDERING THE EFFECT OF TENSION PULLEY

The final dynamical equation which has been obtained by combining the dynamics of the energy converter with that of the tension pulley is

$$\left[\frac{I}{R_m}+\left(M_c+M_f\right)R_m+\left\{\frac{\rho_w C_M \pi d_f^{\,2}}{4}\left(h+x_w-R_m\theta-\Delta L\right)\right\}R_m\right]\frac{d^2\theta}{dt^2}$$
$$+\frac{1}{R_m}\left(C+\frac{G^2 k_e k_\tau}{r}\right)\frac{d\theta}{dt}=\left(M_c-M_f\right)g \tag{1}$$
$$+\frac{\rho_w g \pi d_f^{\,2}}{4}\left(h+x_w-R_m\theta-\Delta L\right)$$
$$+\frac{1}{8}C_D\rho_w\pi d_f^{\,2}\left|\frac{dx_w}{dt}-R_m\frac{d\theta}{dt}-\frac{d\Delta L}{dt}\right|\left(\frac{dx_w}{dt}-R_m\frac{d\theta}{dt}-\frac{d\Delta L}{dt}\right)$$

where θ is the anticlockwise angle of rotation of the driving pulley, M_f is the mass of the float, M_c is the mass of the counterweight, I is the moment of inertia of all the rotating components, R_m is the radius of the driving pulley, d_f is the diameter of the float, ρ_w is the mass density of water, h is the initial submerged height of the float, x_w is the instantaneous water surface displacement, g is the gravity acceleration, C_D is the drag coefficient, and C_M is the added mass coefficient, ΔL is the net change in the length of the cable due to the effect of the tension pulley, G is the total gear ratio, k_τ. is the torque constant of the generator and k_e is its voltage constant.

3. CALCULATION RESULTS

The specifications for the wave energy device and the tension pulley used in this study are given in Table 1. Fig. 3 shows the time series of the cable tension for two

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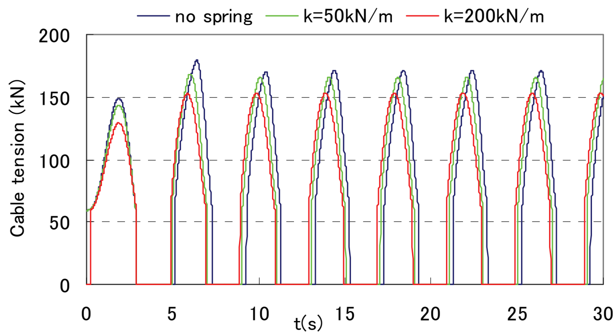
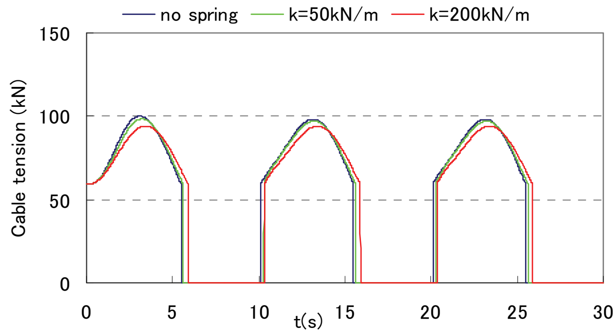


(a) H=3m, T=4s



(b) H=3m, T=10s

Fig. 3 Time series of the cable tension indicating the effect of the tension pulley

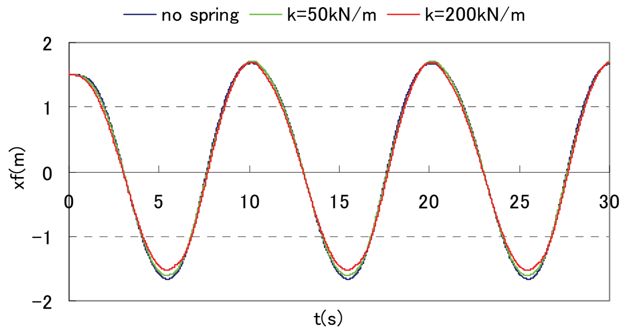


Fig. 4 Time series of float displacement indicating effect of tension pulley (H=3m, T=10s)

wave conditions: H=3m, T=4s and H=3m and T=10s. From the figures, it can be observed that the peak value of the tension force is significantly reduced by the action of the spring pulley. Also, the occurrence of negative tensile force is completely eliminated as indicated in Table 2. This is the major objective of the application of the tension pulley. Physically, as the float tends to move upwards due to the rising water level, the spring extends and prevents the cable from becoming slack. For longer wave periods, the effect is not as pronounced as compared to shorter wave periods seen in Fig. 3(b). The

Table 1 Specifications of the device and tension pulley

Float	Mass density ρ_f (kg/m^3)	900	
	Height H_f (m)	3	
	Diameter D_f (m)	3	
	Submergence ratio	0.6	
	Mass M_f (kg)	19085	
Counterweight	Mass M_c (kg)	6044	
Driving Pulley	Radius R_m (m)	0.4	
Gear Box	Gear ratio G	40	
Generator	Voltage constant k_e (V/rpm)	0.7639	
	Torque constant k_τ (Nm/A)	1.2838	
	Internal resistance r (Ω)	0.26	
Tension Pulley		Wave Height H	
		0.25-1.5	2.0-4.0
	Spring Constant k (kN/m)	20-100	120-200
	Orginal length of spring y_0	0.5	1.5
	Horizontal projection of cable length l_1,l_2 (m)	1	1

Table 2 Minimum value of the cable tension indicating the elimination of negative tension due to the application of the tension pulley

Wave period T(s)	4	5	6	7	8
Without tension pulley	-29.1kN	-31.1kN	-26.2kN	-13.0kN	-2.4kN
k=120kN/m	6.8kN	8.6kN	11.7kN	15.0kN	18.1kN
k=200kN/m	1.9kN	3.5kN	7.0kN	10.9kN	14.6kN
Wave height H = 3m					

time series of the float displacement, shown in Fig. 4, indicates that the peak displacement amplitude in the down-stroke is suppressed. This helps in preventing the total submergence of the float which is undesirable from the point of view of energy gain and safety of the device[1].

CONCLUSIONS

From the numerical solution of the modified dynamics model, the following conclusions can be drawn:

a) the tension pulley is successful in suppressing sharp fluctuations of the cable tension.

b) the effectiveness of the device is more pronounced for short wave periods and high wave heights.

REFERENCES

1)Hadano, K, Taneura, K, Watanabe, M., Nakano, K, Saito, T, and Matsuura, M (2006). "On the dynamics of the float type wave energy conversion", *JSCE Journal B*, vol 62, No. 3, pp 270-383, CD-ROM. (in Japanese)