Analysis of a vibrating device based on a dielectric elastomer oscillating water column

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Abstract

Dielectric elastomer as the actuators and sensors have been largely studied, applied research in the field of energy collection is less. The dielectric elastomer has light weight, low cost, high corrosion resistance, high pressure and their inherent periodic operation mode suitable for obtaining mechanical energy from the waves. So far, there are limitations of the development of high performance wave energy converter. The wave energy converter is based on the traditional mechanical parts, hydraulic transmission and electromagnetic generator, but are stiff and bulky, heavy and expensive metal materials, therefore, the existing wave energy converter is expensive, difficult installation, corrosion and can not adapt to the marine environment. The dielectric elastomer generator technology is an enabling technology that can overcome the limitations of the current wave energy converter technology. Under this kind of background, we The oscillation of water column in the near coastal oscillation wave energy conversion device is analyzed.

Keywords

Oscillating water column, Dielectric elastomer, Simulation.

1. Introduction

The oscillating water column type power device on the dielectric elastomer generator is analyzed, the vibration of the wave energy collection device by using sealed in the gas chamber, the shock waves can be converted into gas pressure. The structure of the paper is as follows, first on the oscillating water column type power device modeling, dynamic analysis of the source of the pressure device. The device can be provided by using Simulink modeling calculation, and analysis of indoor air pressure, the relationship between dielectric elastomer film and the displacement amplitude.

2. Introduction of dielectric elastic oscillating water column

2.1 The advantages of dielectric elastic oscillating water column

Low cost: dielectric elastomer is a relatively inexpensive material, and has the advantages of simple structure and reduce the generator internal electrical components (additional inverter, transformer, etc.) so that people develop wave energy converter can reduce capital and operating costs.

Easy to install and maintain: dielectric elastomer generators are light weight, so they do not require high-grade mechanical installation tolerances, and do not require moving or mounted powerful movers; corrosion resistance is good.

High energy efficiency: polymer oscillating water column can be more efficient than the turbo oscillating water column: friction loss limited, larger bandwidth and power loss limited. However, still need to realize that this higher energy conversion efficiency of this technology.

Reduce noise: polymer oscillating water column operating below turbine vibration water column, so more suitable for installation in coastal areas (such as ports).

2.2 Several implementation schemes

(1) direct pressure type: dielectric elastomer film directly covered in one or more chamber oscillating water column opening. Figure 1 shows a possible implementation. As an example, the dielectric elastomer film can be spherical or cylindrical.

(2) indirect: the pressure in the chamber of the dielectric elastomer film acts completely on the other elements, such as the moving piston (see Figure 1b). This can be configured by different structures, such as a cone or diamond.

(3) hybrid dielectric elastomer film is connected to some additional movable rigid components. The chamber pressure directly on the dielectric elastomer film and rigid elements (see Figure 1c). The possible solutions for the development of a uniform strain or strain sensor amplification effect.

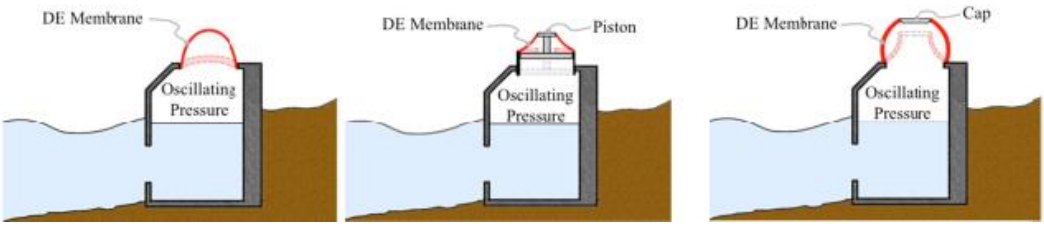

Fig. 1 Schematic diagram of possible realization of polymer oscillating water column

3. Polymer oscillating water column model

The analysis, design and control of polymer oscillating water column need enough physical model to represent the complex interaction between waves, the structure of oscillating water column compression / expansion of the air and the generator. The continuous calculation of multiple physical model of polymer oscillating water column is very complicated and harsh, especially 3D calculation.

With this idea, preliminary work is considered the ideal two-dimensional problem, as shown in Figure 3. The system includes a fixed rectangular shape oscillating water column structure, open a hole and the cylindrical surface of dielectric elastomer film is used as a power output mechanism.

The space of the horizontal and vertical coordinates of X and Z, depth HB. width C sink from the oscillating water column structure$-\infty \le X \le 0$ extension and having a constant and forward air chamber wall (x = 0), and the submerged hole through the constant a and B distance measurement. The average water level oscillating water column includes a gas chamber the extended length d from the rectangular part generated, plus (or minus, as shown in Figure 2) cylindrical section level, is based on the string 2e and pointy high H dielectric elastomer film. As shown in Figure 3, Patm is a constant atmospheric pressure in the air - water interface, gas chamber the pressure in the chamber and water interface, and PE is in the water.

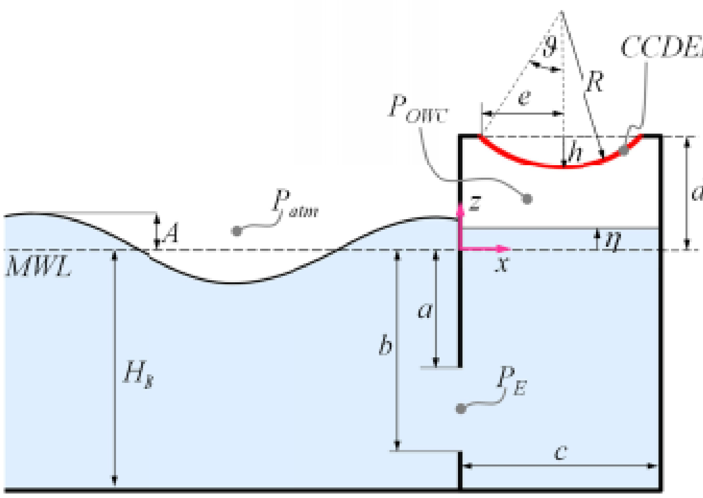

Figure 2. Model of polymer oscillating water column and related geometric parameter scheme

Oscillations in the hollow structure described in the water column motion equation 2 can be written

$$\ddot{\eta}=\frac{\text{Patm}+P_E(t)-P_{OWC}(t)-\rho_w g\eta-D_1\dot{\eta}}{\rho_w(a+\eta)} \tag{1}$$

Where ρw is the density of seawater, D1 is a linear damping coefficient of hydraulic loss in oscillating water column, water displacement curve for ETA oscillation, PE as a spatial average (along Z coordinate) of the dynamic pressure field in the front wall of the oscillating water column (x = 0), i.e.

$$P_E(t)=\frac{1}{b-a}\int_{-b}^{-a}P_E(0,z,t)dz\approx\frac{2\rho gA}{b-a}\frac{\sinh[K(H_B-a)]-\sinh[K(H_B-b)]}{K\cosh(KH_B)}\cos(\omega t) \tag{2}$$

Among them, g is gravity acceleration, A is amplitude, K is wave number, and t is time variable.

$$P_{OWC}(\text{t})=\mu\frac{\partial\Phi}{\partial t} \tag{3}$$

Where Φ is the velocity potential, μ is the effective damping coefficient of gas indoor air lift oscillation.

$$\Phi(x,z,t)=-\frac{2gA}{\omega}\frac{\cosh[K(z+H_B)]}{COS(KH_B)}\cos(Kx)\sin(\omega t) \tag{4}$$

C and e are constants. Then the equations of motion for dielectric elastomer films are

$$\rho_d t_0\lambda^{-2}(g+\ddot{h})+\frac{2t\sigma}{R}=P(owc)\text{-}Patm \tag{5}$$

t0 is the thickness of the dielectric elastomer film after deformation, and ρd is the water density

$$\lambda=\frac{\text{h}^2+e^2}{ee_0} \tag{6}$$

$$\sigma=\sigma_{\text{el}}+\sigma_{es} \tag{7}$$

among

$$R(h)=\frac{h^2+e^2}{2h} \tag{8}$$

4. Simulation result

This section is devoted to the calculation of the potential performance of a polymer oscillating water column, such as calculations of dielectric elastomer film parameters for changes in the film. Here are some of the main parameters HB = 8 m, a = 6 m, b = 8 m, c = 12 m , d = 7.29 m , e = 6 m, t0 = 0.01 m , C0 = 1.37e9, Im=430, ε=4.5×8.85×10-12F/m, V=200v, e0=5, μ=0.6, γ=1.4

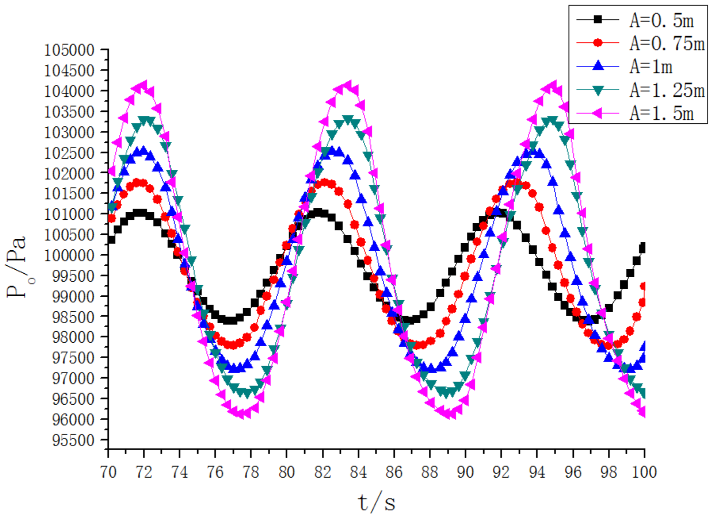

Fig. 3 Powc variation curve with amplitude

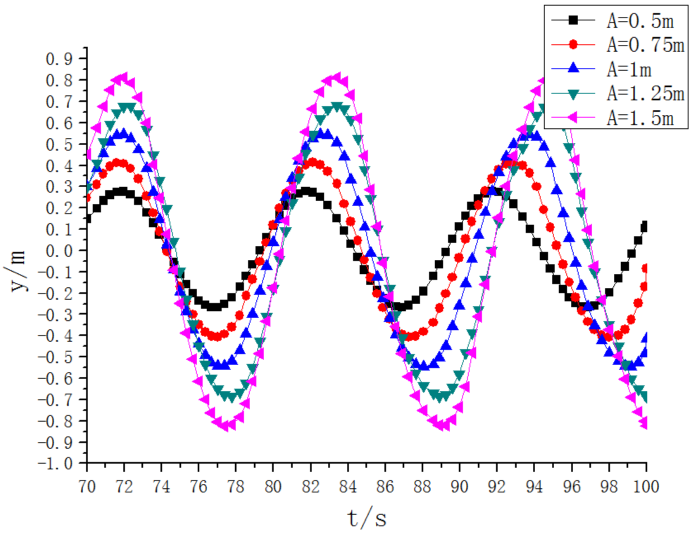

Fig. 4 curves of oscillating water column with wave amplitude

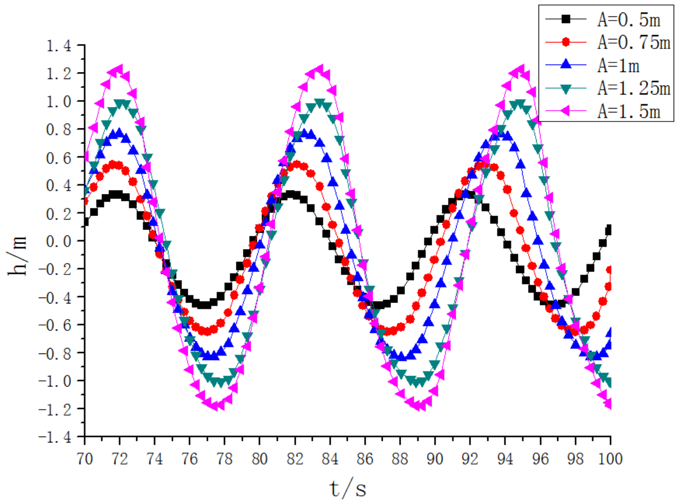

Fig. 5 displacement curves of dielectric elastomer film with wave amplitude

Figure 3,4,5 can be seen when the amplitude of A=0.5m, 0.75m, 1M, 1.25m, 1.5m gas pressure indoor POWC, oscillating water column displacement and dielectric elastomer film displacement is increased with the increase of the amplitude and the influence

5. Conclusion

In this paper a method of solving the OWC wave energy conversion device of the indoor gas water movement equation, and the solution of the gas chamber pressure and the dielectric elastomer film displacement, so as to analyze the influence of amplitude. The simulation results are obtained by the numerical model, we can see that the working principle of the oscillating water column. The next task is to study the energy conversion efficiency of dielectric elastomer oscillating water column.

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