Analytical and Modelling approach to convert tidal wave energy into electricity through DIELECTRIC ELASTOMER by using MATLAB

ROHIT SHUKLA[1], MAHEEDHAR DUBEY[2] and MANOJ KUMAR DEWANGAN[3]

[1]M.TECH SCHOLAR,
[2]ASSISTANT PROFESSOR*,
[3]ASSISTANT PROFESSOR
VISHWAVIDYALAYA ENGINEERING COLLEGE, AMBIKAPUR (C.G)

Abstract: Ocean wave energy is a renewable source of energy, it's clean and abundant source of energy becomes the central topic of modern scientific research. Because there is no any such a good technology exist to convert the mechanical energy of tidal wave into electricity.

Here in this context we show that natural rubber(NR) a types of dielectric elastomer(DE) which we used as generator is a class of capacitive highly stretchable dielectric elastomer generator that convert mechanical energy into high voltage direct current electricity.

In this paper the oscillating tidal wave energy converted into electricity by taking the advantage of high fracture strength, good dielectric constant, low cost and abundantly availability of natural rubber and it's composites, due to low levelized cost NR can be used as a large scale production of electricity.

Keywords: **Dielectric elastomer, Generator, Actuator, Natural rubber, Capacitance OWC, CD DEG, etc.**

1. INTRODUCTION

Renewable energy harvesting is an important topic of modern times scientific and technical research. in recent decades Efforts to promote primary energy consumption the move to increase the share of "green energy" has led to the research and development of new technological solutions that can ensure the efficient use of renewable energy sources. In this context, several types of dielectric elastomer material based on innovative technologies multifunctional have been studied in Attempts to provide innovative solutions directly.

Mechanical-electrical conversion of energy from energy sources in the environment. Energy harvesting from the environment Vibration and flow of air or liquid. Through the use of piezoelectric [1], electromagnetic, turboelectric [2] and electrostatic [3] generators.

A particularly interesting class of these generators is: It is represented as a generator of dielectric elastomers (DEGs) [4]. DEG - one or More flexible and deformable dielectric sheet material covered with a stretchable conductive electrode. According to the principle of operation DEG - variable capacitor capable of transforming the machine work used into DC Electric current. their first demonstrated[3] Research in multiple applications such as energy harvesting From human movement, water flow and waves.

Compared with conventional electromagnetic generators, Undoubtedly, DEGs are characterized by simpler architectural solutions. Mass density, fewer components, potentially higher Reliability and low cost. These promising features have attracted attention. Interest of several researchers who have worked hard It increases the performance of the DEG and demonstrates its ability to efficiently produce more power. Electrical energy (DE) per unit mass of dielectric elastomeric material [5]. It undergoes an isometric deformation [6]. Over the past few years, This promising number has awakened the interest of the sea Energy community with a particular focus on emerging energies wave energy sector. The energy of the waves is abundant It is a highly concentrated renewable energy source, but Operation is still limited to real plants and pre-commercial prototypes [7],current wave energy converter (WEC) based on traditional technology Excessive complexity and cost, low tolerance to the ocean Environmental and limited energy conversion efficiency.

To reduce such type of problem natural rubber and it’s composites(a type dielectric elastomer) material is taken in this paper, it has high energy density[5] then acrylic elastomer VHB 4905,the natural rubber dielectric elastomer is easily available, low cost, have high elastic modulus, but more viscoelasticity, it has low tangent loss[8].

2 COMPARISION REVIEW

Dan Yang et al[1].In this paper different properties of natural rubber composites and VHB is compared and found that the NR composites have great potential in DEGs and DEAs applications, such as energy harvesters and soft sensors.in this paper researcher enhanced the energy density and conversion efficiency of natural rubber and it’s composites by adding nanoparticles, barium titan ate(BT) and dactyl phthalate(DOP) in NR matrix, in doing so a low elastic modulus and high dielectric constant is obtained as well as actuation property improved. Hence NR composites can be used for both purpose for energy harvesting and for actuation.

Federico Carpi et al[2]. A brief introduction about electro active polymer and it’s types, the area of application. The reader should be able to understand how EAPs can enable bio inspired motion systems after reading this outline. Large active strains in response to driving voltages, high power density, high mechanical compliance, structural simplicity and versatility, scalability, no acoustic noise, and, in most cases, low costs are among the functional and structural properties of EAP actuators that are unmatched by traditional actuation technologies (namely electrostatic, electromagnetic, and piezoelectric).

D. Peter et al [3]. This paper presents a simple proposal for an electret-based electrostatic converter that can be used to convert low density energy sources on a big scale. The converter is a capacitive charge pump with a high conversion efficiency and the ability to operate at low frequencies (less than 1 Hz).

The converter may work without an initial bias voltage source since it uses a charged electret-like elastomer membrane. The mechanical input energy was 332J (9.1J/cm2) and the converted electrical output energy was 206J (5.7J/cm2) per conversion cycle in the first experiments with a modest proof-of-concept demonstration.

Rozaidy C.Y. et al[4]. Simulation is used in this study to determine the electrode material and parameters that optimise strain performance. In this paper researcher made a simulation of DE by using COMSOL and the deformation of DE is studied by using three types of electrodes that is Graphite, Carbon grease and Carbon powder.
They found that the graphite electrode gives better result that is highest stress at 2KV as compared to other electrode.

C.L. Zhang et al[5].Harvesting energy from regular contact type displacement excitation by using two dielectric elastomer membranes of VHB4910.In this paper analytical and numerical simulation are made and it is found that energy harvesting can be improved with large amplitude and smaller period of exicitation,the energy harvesting performance can be enhanced by increasing the prestretch ratio, plate radius while decreasing the DEMs radius.

Giacomo Moretti et al[6].The first demonstration of a DEG system capable of converting the oscillatory energy carried by water waves into electricity is described in this study.A L-shaped OWC prototype is made and experimental study is carried in this paper .the tidal wave energy is utilised in increasing the pressure and that pressure is creating a force on the CD-DEG which expended due the mechanical pressure force, that stretched energy converted into the electrical energy.

Rainer Kilties et al[7].Natural rubber and VHB were compared for gathering ocean wave energy in a comparative study. Natural rubber may be utilised to make high-efficiency, low-cost generators. Natural rubber has a greater elastic modulus, fracture energy, and dielectric strength than an acrylic elastomer that has been extensively researched. In this paper it is investigated that natural rubber has high energy density and power density as compared to acrylic elastomer.it can be used for large scale production of electricity.

Yu Fang Go et al[8]. The tests described in this paper were carried out that theoretically, 1160 present strain can be achieved, but this is not attainable in practise. With a maximum weight of 131.6g, the maximum 503 present strain for VHB4905 electrically actuation will be achieved. Experiment found that the EAP can be stretched electrically, and the stretch EAP stores considerable amount of mechanical energy that can be convert into mechanical power.

3. PROBLEM IDENTIFICATION

The researchers harvested electrical energy from the tidal wave using an acrylic-based circular diaphragm dielectric elastomer generator (CD-DEG) system and observed lower efficiency.

This may be following reason to have lower efficiency.

1. The employed material (VHB4905) exhibit large viscoelasticity and charge leakage, which affect the CD-DEG efficiency .
2. The material used for the dielectric layer have lower energy density.
3. More electromechanical losses and having low fracture strength.
4. Hydrodynamics losses and sloshing within OWC are prominent aspect of CD-DEG, which lags in literature.

4.MODEL DESIGN

4.1 Designing of CD-DEG:

When no pressure force is applied, the circular diaphragm is initially flat. It is a polymeric unit coated with compliant electrodes and made up of one or more layers of dielectric material. The compliant electrodes are electrically coupled to variable geometry-based capacitors.

It distorted into a hemispherical shape when a pressure force was applied. And the capacitance of the capacitor is altered.

4.2 Basic equation of CD-DEG

Inflated circular diaphragm dielectric elastomer generators (CD-DEG)

e_0 = radius of the DE membrane in its planar undeformed shape.
t_0 = thickness of the DE membrane in its planar undeformed shape.
e = radius after pre-stretch.
t = thickness after pre-stretch.
H = tip elevation height.

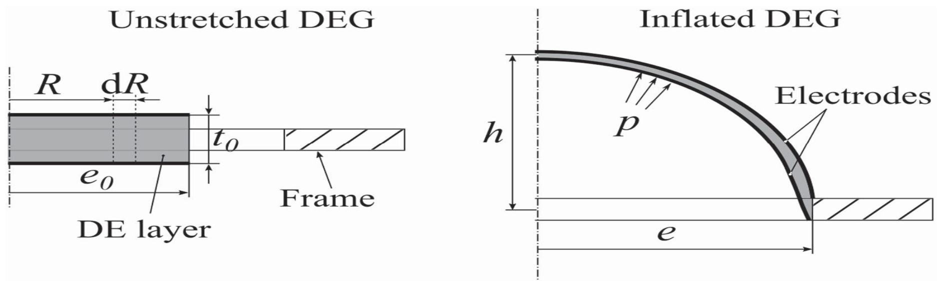

Figure 1: (a) Upstretched DEG and (b) Inflated DEG due to the wave

$$R = \frac{h^2 + e^2}{2h} \tag{1}$$

$$e = \lambda_p e_0 \tag{2}$$

Where

λ_p = radial pre-stretch

$$\lambda(h, R) = e_0 e \frac{h^2 + e^2}{e^2 e_0^2 + h^2 R^2} \tag{3}$$

The volume bounded by the deformed spherical shape Ω_c

$$\Omega_c = \frac{\pi}{6} h\left(h^2 + 3e^2\right) \tag{4}$$

4.3 Capacitance of ICD-DEG:

Variation of capacitance with tip elevation height , the capacitance of the CD-DEG is increases with increase in tip elevation height due to the pressure that is applied by the tidal wave, as the air pressure force is increases the circular diaphragm start inflating and acquire hemi-spherical shape.

$$C_{in}(h) = \left[\left(\frac{h^2 + e^2}{e^2} \right)^3 + \left(\frac{h^2 + e^2}{e^2} \right)^2 + \left(\frac{h^2 + e^2}{e^2} \right) \right] \quad (5)$$

4.4 voltage increase

The CD-DEG deformed by the air pressure generated because of raising or lowering the water level inside the oscillating water column chamber. The shape of deformed circular diaphragm looks like hemispherical it inflated in upward and downward direction during a single wave period. So each wave is responsible for generating two power cycle.

At inflated position the capacitance is maximum the external electric source is applied having priming voltage V_{in} and removed after few seconds, the parallel plate capacitor is charged

The CD-DEG returns to its original position the voltage V_{out} calculated by balancing the initial and final charge on capacitor, because total charge on capacitor remains constants.

Applying energy balance equation

Total charge on parallel plate capacitors and CD-DEG during charging = Total charge on parallel plate capacitors and CD-DEG after charging

$$(Q_t)_{initial} = (Q_t)_{final}$$

$$C_{in}V_{in} + C_a V_{in} = C_{out}V_{out}$$

$$V_{out} = V_{in}\left(\frac{C_{in} + C_a}{C_{out} + C_a} \right) \quad (6)$$

Where

C_{out} = capacitance of CD-DEG when CD-DEG in flat condition , it remains

Constants throughout the cycle.

C_{in} = capacitance of CD-DEG, it varies with tip elevation height.

V_{in} = input priming voltage

C_a = parallel plate capacitors

4.5 Electrical energy generation

After charging, when the external electrical energy sources is disconnected the CD-DEG start returning to its original position(flat condition) and the electrical energy is generated.

The cycle is continuously running ,each cycle produced certain amount of electrical energy so the total electrical energy generated in i^t cycle is given as

$$E_{g,i} = \frac{1}{2}\left(C_{out}V_{out}^2\right)_i - \frac{1}{2}\left(C_{in}V_{in}^2\right)_i + \frac{1}{2}C_a\left(V_{out}^2 - V_{in}^2\right)_i \tag{7}$$

The first term of this equation representing the positive(gained) energy flux through circular diaphragm dielectric elastomer generator(CD-DEG), while the second term is the negative (spent) energy flux through the CD-DEG, and the third term is the overall balance energy flux on the in parallel plate capacitor.

4.6 Average power generated.

Total average power generated for' n' number of generation in the i^t cycle can be calculated by using the equation (11)

$$P_g = \frac{1}{t_{total}}\sum_{i=1}^{n} E_{g,i} \tag{8}$$

$$P_g = \frac{1}{t_{total}}\sum_{i=1}^{n}\left[\frac{1}{2}\left(C_{out}V_{out}^2\right)_i - \frac{1}{2}\left(C_{in}V_{in}^2\right)_i + \frac{1}{2}C_a\left(V_{out}^2 - V_{in}^2\right)_i\right] \tag{9}$$

5. CONCLUSIONS

The suggested system is based on an electrostatic variable capacitor with an inflated CD-DEG built of an acrylic dielectric layer NR composites(30phrDOP/50phrBTmaterial) were created by combining BT nanoparticles with a DOP plasticizer to increase the electric energy density and energy conversion of DEGs and compliant electrodes. The synergistic impact of BT nanoparticles and DOP plasticizer, which was achieved by adjusting the filler network and polymeric intermolecular attractions, resulting in an amazing combination of mechanical and dielectric properties with a high dielectric constant and a low elastic modulus.The CD-DEG is connected to a nonlinear harmonic oscillator, which consists of a collector that confines a mass of water, i.e. an OWC, which is set in reciprocating motion by water waves' hydrodynamic pressure. The CD- DEG is capable of converting a relevant fraction of the incoming wave power into direct-current electricity with adequate electrical control. The developed a design strategy that maximises converted power within a certain range of wave frequencies by providing resonant response of the system. the NR composites have great potential in DEGs and DEAs applications, such as energy harvesters and soft sensors.

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