Volume 8 Issue 4 (2020) 405-408 ISSN 2347 - 3258
International Journal of Advance Research and Innovation

# Design of Dielectric based Unimorph for enhanced Bending

Ashutosh Singh, Jitendra Bhaskar
Department of Mechanical Engineering, Harcourt Butler Technical University, Kanpur (UP), India.

**Article Info**
Article history:
Received 20 February 2020
Received in revised form
20 October 2020
Accepted 28 October 2020
Available online 15 December 2020

**Keywords:** Soft robotics, smart materials, Dielectric elastomers, Unimorph

**Abstract:** It is vital to determine or extract the highest obtainable wind energy at any wind speed because of the natures unforeseeable wind limitations. Therefore, a smart controller that can monitor the extreme pitch irrespective of wind velocity. This article concentrates on several previous and present techniques for achieving maximum wind energy capacity. The maximum power point tracking (MMPT) solution is numerous, but the issues lends itself to their efficient selection and requires expert understanding about every method to choose an efficient MPP method, as such method alone presents some benefits and drawbacks. Different MPP techniques are discussed and compered in terms of convergence moment, effectiveness, training and implementation complexity and they are characterized based on continual wind speed as well as variable wind speed.

## 1. Introduction

Electroactive Polymer materials for the last three decades have been studied and described by the study of their mechanical or electrical reactions subjected to thermal, chemical, friction, optical or magnet fields; certain similarities or effect on their electromechanical properties is identified by the external stimuli. Smart polymers are engineered to react to a stimulus and in recent decades have been studied and used in many developments. One category of such materials is formed by electroactive polymers. Electroactive polymers are materials which, introduced to an electric field, change their shape and size. Electroactive polymer systems can also transform mechanical forces into electrical signals which are desirable and effective for sensors and energy production.

Dielectric elastomers (DEs) is a class of electro-active polymers which works on principle on applying electric field on DEs, due to which deformation in the DEs i.e natural rubber piece demonstrated by Wilhelm Conrad Roentgen in 1880. A typical configuration of DEAs is a sandwich between two compliant electrodes of a soft elastomer membrane. The resulting electrical field induces thickening and an increase in membrane area when a voltage is applied between the electrodes. Multifunctional dielectric elastomers provide excellent characteristics for future soft robotic technologies. Dielectric-based elastomer actuator (DEA) has promising applications in soft-robotics. DEAs have essential components as compliant electrodes with a high degree of stretchability and conductivity.

Dielectric EAPs are materials in which the electrostatic forces generated between two electrodes that compress the polymer are responsible for their motion. Dielectric elastomers are capable of very high stresses and are essentially capacitors that adjust their efficiency when a voltage is applied so that the polymer can contract and extend into the region to the electric field. This form of EAP produces high electric fields, but very low power consumption usually requires large actuation voltage. Dielectric EAPs do not need power to maintain a certain location of the actuator.

The figure1 shows the principle of dielectric elastomer. On applying voltage, electrostatic pressure is developed due to which Ui ntt ( zm (q(wj iqvnl(w m( pn(jmiu 6

Polyimide, Parylene-C and polyethylene having the dielectric properties and also have soft in nature, which elongate on applying voltage over it.

In this research paper, electro-mechanical analysis of dielectric elastomers based design of soft gripper considering as an unimorph beam have been performed applying high voltage in the range of 2kV - 7kV on different DE materials. Extension and Bending performance have been analyzed.

**Corresponding Author,**
**E-mail address:** shume619@gmail.com; bhaskar48m@yahoo.com

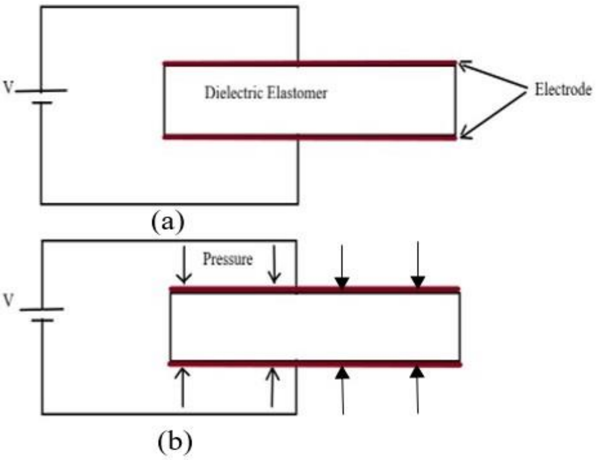

**Fig.1**: Schematic diagram of Dielectric elastomer (a) Not in active state (b) activated state.

## 2.Methodology

In this proposed design of dielectric elastomer consist of three layers. Out which one layer made of non-electrically conductive softer polymeric material which works as passive and other two layer, made of dielectric works as active alternatevly (figure 2). Compliant electrodes are made on both side of dielectric elastomers(Tw (a w vo (Uwl t (u i mzqit(q( ntnkml(nvz(xi q n( layer.

The mechanism behind the design of bending of the gripper is the change in shape at the high voltage pressure between the electrodes. The dielectric layer is compressed by high pressure. This dielectric is confined on the side of the length so that there is no deformation on this side. The material shifts the form longitudinally due to all the strains within the beam. Because of this stress, an offset force is applied in a longitudinal direction over a cross sectional beam area which develops indirectly a beam bending moment. This way the beam curves the end of the beam with the requisite strength to grasp the weaker objects.

The analytical model of the working of this proposed design is given here. Euler-Bernoulli model has been used for two layered beam (Kamal et. al) with induced strain.

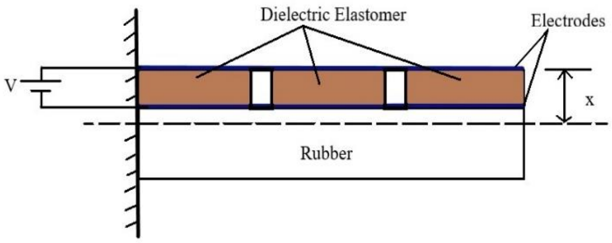

**Fig. 0:** Basic diagram of beam with DE

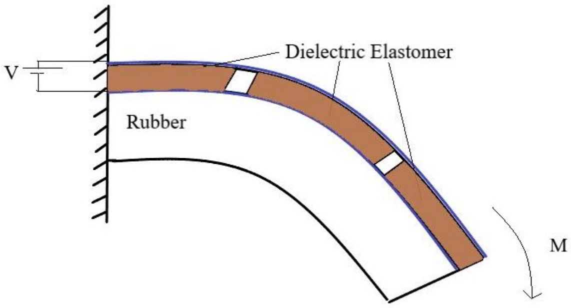

**Fig. 3:** Bending due to Voltage applied

The Euler-Bernoulli model is a consistent strain model and generally gives more accurate results for slender beams than the uniform strain model. So, using this approach for the calculations of extension and bending is obtained.

A generic design for dielectric actuator as a cantilever beam is presented in figure 2 and figure 3. The material of DE can be varied according the need of the analysis as shown in figure 4.

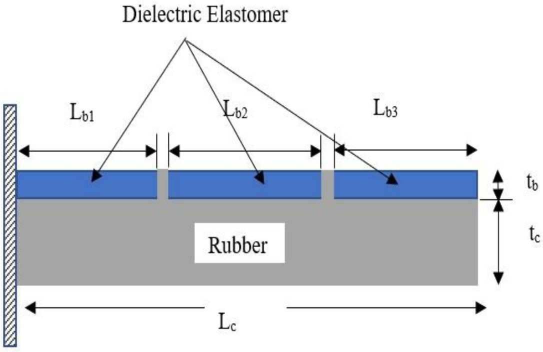

**Fig.4:** Cantilever beam of discrete DE layer and Rubber material

The voltage is applied to the electrodes which causes the strain to bend with the thickness of the Dielectric beam. The bending stress along the electrode's length is assumed to have no change.

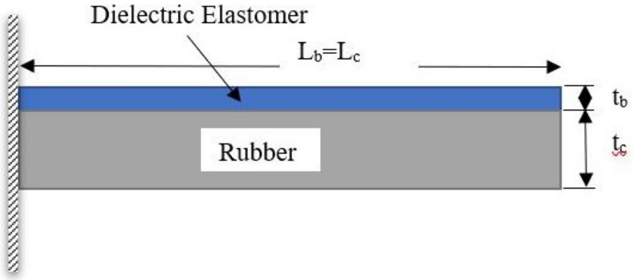

**Fig.5:** Cantilever beam of continuous DE layer and Rubber material

Mi ntt ( zm (nwz(l qtmk zqk(j miu B(

$$\sigma_c = \in \in_\circ \left(\frac{V}{t}\right)^2 \qquad 6091$$

Force due to stress will be:

$$F_c = \sigma_c \times A \qquad 60\ 1$$

So, longitudinal stress in the beam:

$$\sigma_{axial} = \frac{F_C}{A_b} \qquad 60;\ 1$$

Let, location of neutral axis is at $y_1$ from bottom.

$$M_\wedge = F_c \times h \qquad 60\ 1$$

Where, $h = \frac{t_b}{2} + t_c - y_1$

The bending deflection of the beam can be calculated from the bending moment, which is assumed constant within the length of the beam covered by the Dielectric material.

The cross-section of the beam with the different layer positions. An electric field causes the beam to bend and extend. The balance of strength and moment achieved by the cross-section integration provides the control equations.

$$\begin{Bmatrix} F + F_\wedge \\ M + M_\wedge \end{Bmatrix} = \begin{bmatrix} EA_{tot} & ES_{tot} \\ ES_{tot} & EI_{tot} \end{bmatrix} \begin{Bmatrix} \in_o \\ w'' \end{Bmatrix} \qquad (5)$$

In the absence of external loads $F = 0$ & $= 0$, equation (5) can be for general bending case:

$$\begin{Bmatrix} F_\wedge \\ M_\wedge \end{Bmatrix} = \begin{bmatrix} EA_{tot} & ES_{tot} \\ ES_{tot} & EI_{tot} \end{bmatrix} \begin{Bmatrix} \in_o \\ w'' \end{Bmatrix} \qquad (6)$$

Where $w'' = \frac{\partial^2 w}{\partial x^2}$

$$EA_{tot} = E_b b_b t_b + E_c b_c t_c$$

$$ES_{tot} = E_c b_c t_c \left(\frac{t_c}{2} + \frac{t_b}{2}\right)$$

$$EI_{tot} = \frac{1}{12} E_b b_b t_b^3 + \frac{1}{12} E_c b_c t_c^3 + E_c b_c t_c \left(\frac{t_c}{2} + \frac{t_b}{2}\right)^2$$

The forces and moments due to free strain of dielectric material are given by

$$F_\wedge = E_c b_c t_c \wedge \qquad (7)$$

$$M_\wedge = -E_c b_c t_c \left(\frac{t_c}{2} + \frac{t_b}{2}\right) \wedge \qquad (8)$$

So, assuming pure bending case $ES_{tot} = 0$ in equation (7)

$$F_\wedge = EA_{tot} \in_o \qquad (9)$$

Mid plane strain $(\in_o) = \frac{F_\wedge}{EA_{tot}}$ (10)

pm( j mvl qvo( l mtmk qw( $w$ ( mz( ki v qm mz( j miu ( i ((( $0 \leq x \leq (L_c = L_b)$ and at neutral axis where mid plane strain $\in_o = 0$, and putting boundary condition $\left({\partial w}/{\partial x}\right) = 0$ and $w = 0$ both at $x = 0$:

$$M_\wedge = EI_{tot} \frac{\partial^2 w}{\partial x^2}$$

$$\frac{\partial^2 w}{\partial x^2} = \frac{M_\wedge}{EI_{tot}}$$

$$w = \frac{M_\wedge}{EI_{tot}} \frac{x^2}{2} \qquad (11)$$

Now using Bending Moment equation, Radius of curvature of the finger is calculated,

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Radius of Curvature,

$$R = \frac{EI_{tot}}{M_\wedge}$$

$$\theta = \frac{1}{R}$$

For all the dielectric film over Rubber gives the total slope will be,

$\theta = \theta_1 + \theta_2 + \theta_3$

Also, comparison between the continous layer of TPU and discrete layer of TPU on applying different voltages as shown in figure 4 and figure 5.

## 3. Materials Selection and Design:

Different materials are used for bending behaviour of unimorph and bimorph dielectric beam. Materials are polyimide, thermoplastic polyurethane and parylene-C

### 3.1Properties of Thermoplastic Polyurethane

a w vo (U wł t = 2410 MPa
Xwq ww (zi qw = 0.38
Relative Permittivity = 6.5
Electric Potential Range = 4 kV to 7 kV
Permittivity of Space = 8.85 * $10^{-12}$ F/m

### 3.2 Properties of Polyimide

a w vo (U wł t = 2500 MPa
Xwq ww (zi qw = 0.34
Relative Permittivity = 3.4

### 3.3 Properties of Parylene-C

a w vo (U wl t = 2900 MPa
Xwq ww (zi qw = 0.4
Relative Permittivity = 6.5

### 3.4 Properties of Polyethylene

a w vo (U wl t = 1070 MPa
Xwq ww (zi qw = 0.34
Relative Permittivity = 2.25

### 3.5 Properties of Rubber

a w vo (U wl t = 50 MPa
Xwq ww (zi qw = 0.47

### 3.6 Dimensions of Specimens

$L_b = 65\ mm$
$L_c = 65\ mm$
$b_b = 15\ mm$
$b_c = 15\ mm$
$t_b = 0.5\ mm$
$t_c = 4\ mm$
$A_c = 30\ mm^2$
$E_c = 50\ MPa$

## 4. Result and Discussions

Using MATLAB programming for the calculation of deflection and curvature of beam the following results are obtained, figure 6, shows the change in deflection, on varying voltage with changing the Materials of upper layer of beam and figure 7, shows the variation on curvature of beam on varying voltage with changing the material of upper layer of beam and rubber beam.

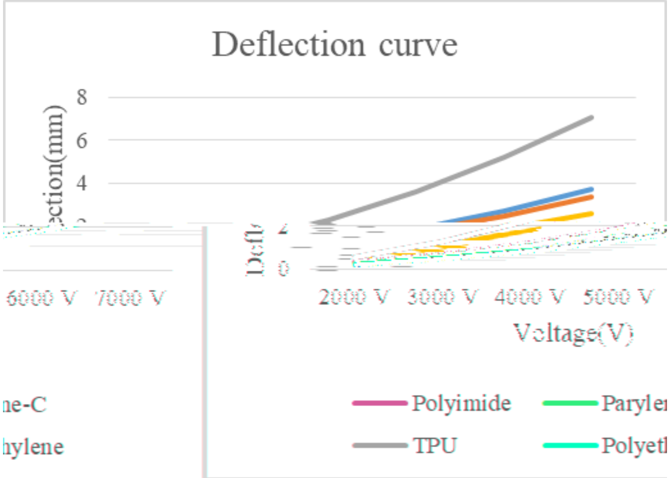

**Fig.6:** Deflection curve of beam on changing voltage and material

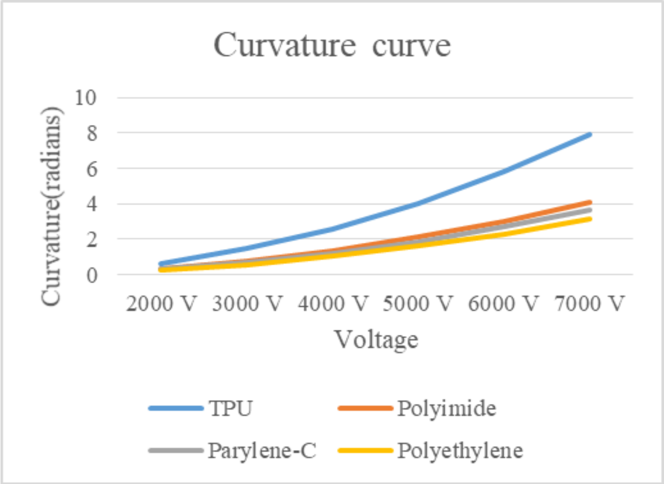

**Fig.7:** Curvature curve of beam on changing voltage and material.

From the above figure 6 and figure 7, it is observed that the TPU material has more deflection and has more curvature as compared to the other DE materials i.e. Polyimide, Parylene-C and polyethylene on changing the volatge from 2000V to 7000V.

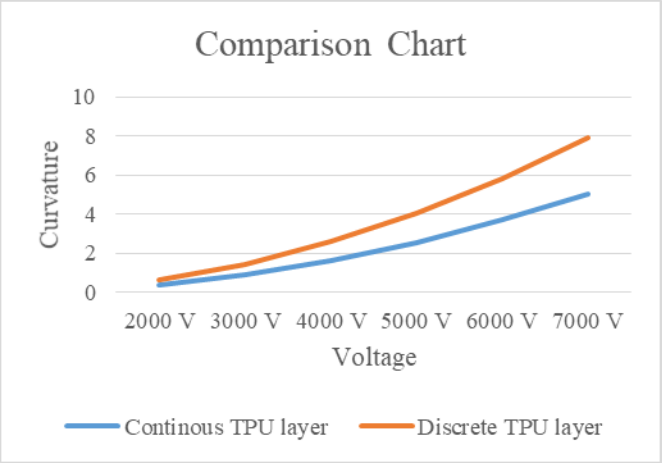

**Fig.8:** Comparison of Curvature between the continous layer of TPU and discrete layer of TPU on applying voltages.

Figure 8, shows that on using the discrete layers of TPU enhances the curvature as compared to the continuous layer of TPU at different voltages.

## 5. Conclusions

In this research work, enhanced bending behaviour of dielectric based gripper was simulated using Euler-Bernoulli model for distributed layered beam. Voltage and dielectric constant of different materials of layers was taken as independent parameters. It was observed from simulation that bending deflection and curvature increase with voltage 2.0 kV to 7.0 kV. TPU is good material for the unimorph finger gripper design as it is observed that on TPU material have more deflection and curvature, as compare to other DE materials i.e Polyimide, Parylene-C, Polyethylene. And on using the discrete layer of TPU enhances the curvature as compared to the continuous layer of TPU.

## Nomenclature

| | |
|---|---|
| b | For showing properties dielectric part |
| c | For showing properties of rubber part |
| $t$ | Thickness |
| $b$ | Width |
| $A$ | Rectangular cross-sectional area |
| $\kappa$ | Bending curvature |
| $w$ | Bending deflection |
| $\Delta l$ | Axial deflection |
| $E$ | Modulus elasticity |
| $EA_{tot}$ | Extensional stiffness |
| $ES_{tot}$ | Coupling stiffness |
| $EI_{tot}$ | bending stiffness |
| $M_{\wedge}$ | Bending moment due to induced strain |
| M | Bending Moment |
| $EI_b$ | Bending stiffness of the Dielectric material |
| $EI_c$ | Bending stiffness of the Rubber |
| $F$ | Axial force in the Dielectric material beam |
| | Dielectric constant |
| R | Radius of Curvature |
| | Curvature of beam |

## References

[1]. J Li, LL Yanju Liu, J Leng. Dielectric Elastomer Spring-Roll Bending Actuators: Applications in Soft Robotics and Design, SORO, Soft Robotics, 2018.

[2]. D Gonzalez, J Garcia, B Newell. Electromechanical characterization of a 3D printed material for dielectric electroactive polymer actuators, Sensors and Actuators A: Physical , 2019. DOI: 10.1016/j.sna.2019.111565.

[3]. F Zhou, X Yang, Y Xiao, Z Zhu, T Li, Z Xu. Electromechanical analysis and simplified modelling of dielectric elastomer multilayer bending actuator, AIP Advances 2020.

[4]. BWJ zqmv4( McKay, E Calius, S Xie, I Anderson. Finite element modelling of dielectric elastomer minimum energy structures, Applied Physics A, Material Science & Processing, Springer-Verlag 2008.

[5]. B Wang, A McDaid, T Giffney, MB Abhari, KC Aw. Design, modelling and simulation of soft grippers using bimorph pneumatic bending, Cogent Engineering, 2017.

[6]. JH Youn, SM Jeong, G Hwang, H Kim, KHyeon, J Park, KU Kyung. Dielectric Elastomer Actuator for Soft Robotics Applications and Challenges, Applied Sciences, 2020.

[7]. S Rosset, OA Araromi, J Shintake. Model and Design of dielectric elastomer minimum energy structures, 2014.

[8]. F Rogti, D Mahi, A Mekhaldi. Study by simulation of the electric field within dielectric environments, International Conference on Solid Dielectrics, 2004.

[9]. J Nzi , M Uikqi , F K jik sq, P [i ms, J O si. Soft flexible gripper design, characterization and application, 12, 2016

[10]. I Chopra, J Sirohi. Smart Structures Theory, 2013

[11]. J Bhaskar, AK Sharma, B Bhattacharya, S Adhikari. A review on shape memory alloy reinforced polymer composite materials and structure, Smart Materials and Structures, 2020.

[12]. K Singh, N Jain, J Bhaskar. Vibrational Analysis of Glass/Carbon Fiber Reinforced Hybrid Laminate Composites, Journal of Theoretical and Applied Mechanics, Sofia, 50, 2020.