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Study of Numerical Analysis on Piezoelectric Materials

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ABSTRACT

In many engineering applications, it is desirable to know the behaviour of structures and Systems under loading conditions. One reason is to help optimize the design and prevent damage and failure which might occur during in service and operation. Damage represents a serious problem which can cause catastrophic failure of structures, machines and systems. Therefore for safe operation, efficient and reliable methods for inspection and monitoring of damage are required. Strain place a major role in damage and failure of structures in order to identify the strain there are several methods. Due to their intrinsic electromechanical coupling behaviors, piezoelectric materials have been widely made into actuators and sensors used in smart structures and MEMS. Present work investigates the comparative study of numerical analysis on piezoelectric material. A finite element method is been chosen for modeling and analyzing for polyvinylidne fluoride (PVDF) and lead-zinc-niobate-lead-titanate (PZT-5T).

Key words: Polyvinylidne fluoride (PVDF), lead-zinc-niobate-lead-titanate (PZT-5T)

1. Introduction

The most popular smart material systems are piezoelectric materials, magnetostrictive materials, shape Memory alloys, Electro rheological fluids, electrostrictive materials and optical fibers. Magnetostrictives,electrostrictives, shape memory alloys and electrorheological fluids are used as actuators while optical fibers are used primarily as sensors[1]. Among these active materials, piezoelectric materials are most widely used [2]. Piezoelectricity is a property of many non-centrosymmetric ceramics, polymers and other biological systems [3-4].

Some of the typical piezoelectric materials include quartz, barium titanante, lead titanate, cadmium sulphide, lead zirconatetitanate (PZT), lead lanthanum zirconatetitanate, lead magnesium niobate, piezoelectric polymer polyvinylidene fluoride (PVDF), polyvinyl fluoride (PVF). The piezoelectric ceramics are highly brittle and they have better electromechanical properties when compared to the piezoelectric polymers [3, 4, and 5]. However, strong piezoelectric effects have been observed only in polyvinylidene fluoride (PVDF or PVF2) and PVDF copolymers [6]. Piezoelectric ceramics are widely used at present for a large number of applications. Most of the piezoelectric ceramics have perovskite structure. Barium Titanate (BaTiO3) and Lead Titanate (PbTiO3) are the common examples of the perovskite piezoelectric ceramic materials.

2. Structural Model

Two Piezoelectric films of opposite polarized are glued together of length 100mm and 50micron thickness, top layer are divided into 10 electrodes as shown below fig 1.

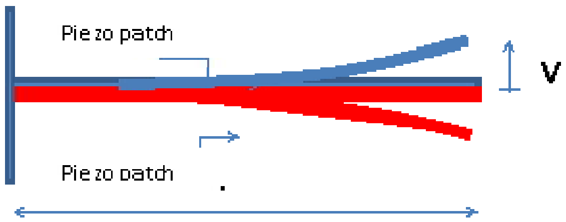

Fig 1 Bimorph Configuration Model

To describe the piezoelectric elements same length and thickness of Piezoceramic as well as Piezopolymer are taken and simple rectangular model are made. Area glue used to stick two layer such a way that top layer and bottom layer are of opposite polarized by changing the coordinates then top layer are divided into 10 electrodes along with this complete model are meshed to .05 element size.one end of the micro lever are fixed and other end are allowed free in one direction that is in y direction as show in fig1.

The results of the numerical analysis are completely divided into two part. Firstly actuation part of two piezoelectric bimorph is discussed next sensing capacity of both same bimorph configuration are taken and results are discussed. For both, configurations remain same and which are discussed in structural mode.

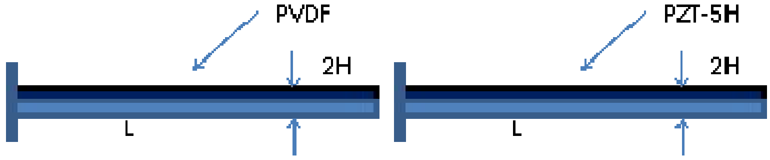

Fig 2 Bimorph Model

Table 1: Material and Geometric properties used for Model validation in Ansys

PARAMETER	PVDF	PZT-5H
Young's modulus	200 GPA	62 GPA
Poisons ratio	.28	.25
density	1690 kg/m^3	7800 kg/m^3
thickness	50microns	50microns
Beam length	1OOmm	100mm
D31	2.2 E-11	274E-12
D32	.3E-11	274E-12
D33	-3.0E-11	-593E-12

Above table 1 presents the parameter's used for modeling micro cantilever bimorph layer and analytical solution also been calculated to compare the results from numerical values.

3.Result and Discussion

3.1Micro Cantilever Bimorph Actuators

Model prepared for different voltages (10v, 20v, 40v, 80v upto 500v) and tip deflection has been taken for study of both piezopolymer as well as piezoceramic . This is well documented in below figure below. Later both are compared to check whether numerical results are matching with theoretical explanation. As per theoretical explanation piezoceramic is a good actuators compared to piezopolyemers due to strain coefficient values and young's modulus. Although piezoceramic is a rigid structure and loses properties easily compared to piezopolymer.

Piezopolymer (PVDF)

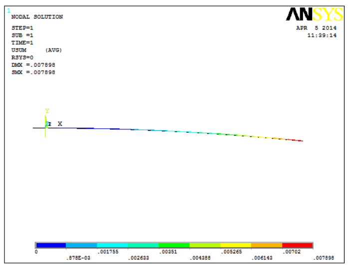

Fig 3 Tip Displacement when Voltage of 240V

Table 2: ***Tip Displacement at different Voltages***

VOLT	LENGTH	THICKNESS	THEORETICAL SOLUTION	ANSYS RESULTS
10	1.00E-01	5.00E-05	3.30E-04	3.29E-04
20	1.00E-01	5.00E-05	6.60E-04	6.58E-04
40	1.00E-01	5.00E-05	1.32E-03	0.001316
120	1.00E-01	5.00E-05	3.96E-03	0.003949
180	1.00E-01	5.00E-05	5.94E-03	0.005923
240	1.00E-01	5.00E-05	7.92E-03	0.007898
300	1.00E-01	5.00E-05	9.90E-03	0.009872
400	1.00E-01	5.00E-05	1.32E-02	0.013163
500	1.00E-01	5.00E-05	1.65E-02	0.016453

Peizoceramic (PZT-5H)

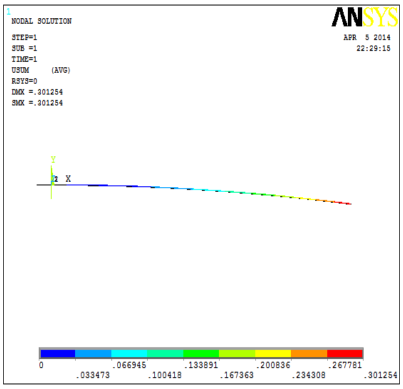

Fig 4 Tip Displacement when Voltage of 240V

Table 3 ***Tip Displacement at different Voltages***

VOLTS	LENGTH	THICKNESS	THEORETICAL SOLUTION	ANSYS RESULTS
10	1.00E-01	5.00E-05	4.11E-03	0.004055
20	1.00E-01	5.00E-05	8.22E-03	8.11E-03
40	1.00E-01	5.00E-05	1.64E-02	0.050209
40	1.00E-01	5.00E-05	1.64E-02	1.00E-01
120	1.00E-01	5.00E-05	4.93E-02	0.150627
180	1.00E-01	5.00E-05	7.40E-02	2.26E-01
240	1.00E-01	5.00E-05	9.86E-02	0.301254
300	1.00E-01	5.00E-05	1.23E-01	3.77E-01
400	1.00E-01	5.00E-05	1.64E-01	5.02E-01
500	1.00E-01	5.00E-05	2.06E-01	6.28E-01

3.2 Micro Cantilever Bimorph Sensor

Model prepared for different tip load (1mm, 2mm ,4mm ,32mm upto 50mm) and sensing capacity of voltage has been taken for study of both piezopolymer as well as piezoceramic .This is well documented in below figure one by one. Modeling is done in such a way that top layer are divided into 10 electrode positions, so at each position it has to sense how much voltage generating in it.

Piezoceramic (PZT-5H)

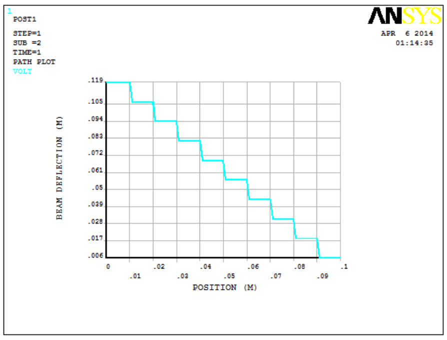

Fig 5 Voltage at different position v/s tip Displacement at 1mm

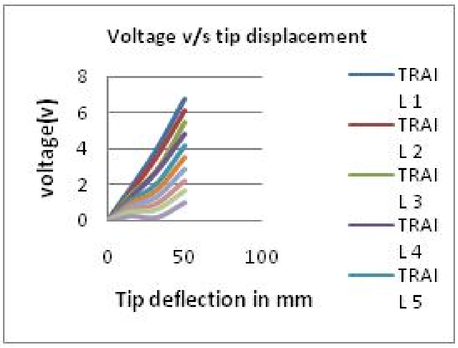

Fig 6 Voltage at different Position v/s Tip Displacements

Table 5: Voltage at Different Position v/s Tip Displacements

Tip deflection	*Voltage (v)*									
(MM)	1	2	3	4	5	6	7	8	9	10
1	0.119	0.105	0.094	0.083	0.072	0.061	0.05	0.039	0.028	0.017
2	0.239	0.22	0.197	0.174	0.151	0.128	0.105	0.082	0.059	0.036
4	0.478	0.43	0.385	0.34	0.295	0.25	0.205	0.16	0.115	0.07
8	0.958	0.869	0.778	0.687	0.59	0.505	0.414	0.323	0.232	0.141
16	1.932	1.747	1.564	1.389	1.198	1.015	0.832	0.649	0.466	0.283
32	4.004	3.62	2.86	2.78	2.1	1.72	1.34	0.96	0.58	0.2
50	6.782	6.138	5.49	4.842	4.194	3.546	2.898	2.25	1.602	0.954

Polyvinyledine fluoride (PVDF)

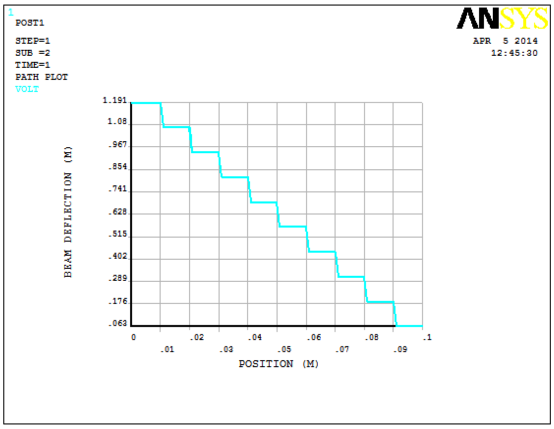

Fig 7 voltage at different position v/s tip displacement at 1mm

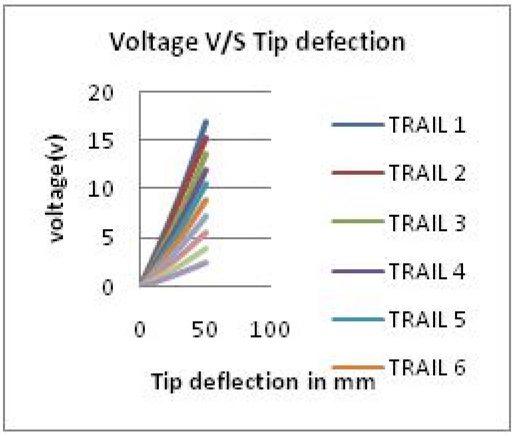

Fig 8 Voltage at Different position v/s Tip Displacements

Table 6: ***Voltage at Different Position v/s Tip Displacements***

TIP DEFLECTION	*ELECTRODE POSITION*									
(MM)	1	2	3	4	5	6	7	8	9	10
1	0.298	0.268	0.24	0.212	0.184	0.156	0.128	0.1	0.072	0.044
2	0.595	0.536	0.48	0.424	0.368	0.312	0.256	0.2	0.144	0.0888
4	1.191	1.08	0.967	0.854	0.741	0.628	0.515	0.402	0.289	0.176
8	2.387	2.16	1.934	1.708	1.482	1.256	1.03	0.804	0.578	0.352
16	4.813	4.356	3.9	3.44	2.988	2.532	2.076	1.62	1.164	0.708
32	9.976	9.626	8.079	7.132	6.185	5.238	4.291	3.344	2.397	1.45
50	16.896	15.288	13.675	12.062	10.449	8.836	7.223	5.61	3.997	2.384

Comparison between Piezopolymer and Piezoceramic as aSensor

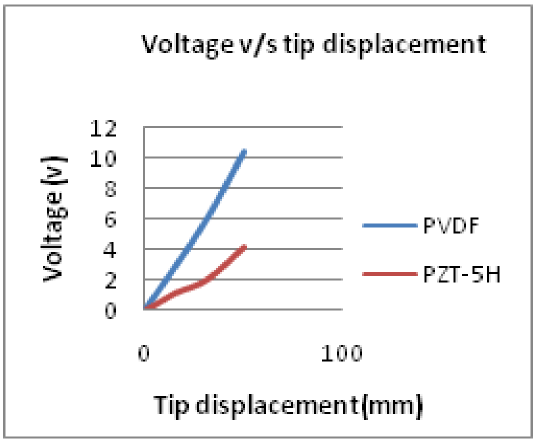

Fig 9 Voltages at far end of the Tip

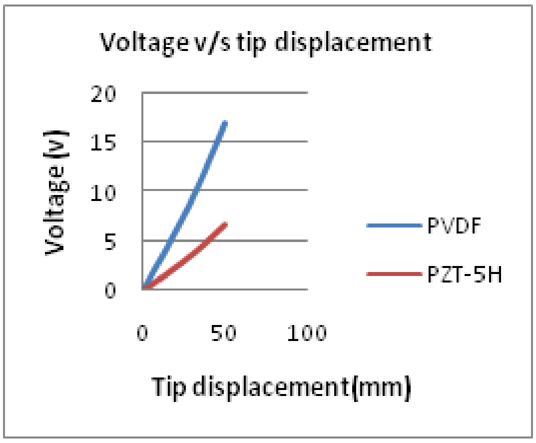

Fig 10 Voltages at near end of the Tip

Comparison between Piezopolymer and Piezoceramic as an actuator

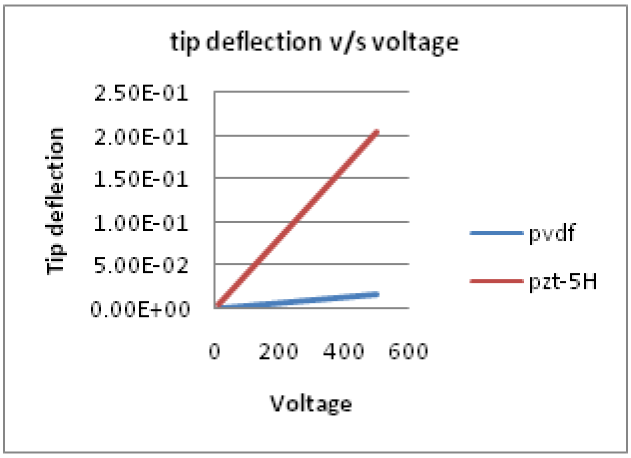

Fig 11 displacement v/s voltage

4. Conclusions

According to the results from the numerical analysis we found both piezoelectric materials are very useful for numerous applications. Both can be used as sensor or actuator but precision does not fallow due to its mechanical properties.

When we come to piezoceramic material PZT, this can be best suitable as actuator compared to PVDF and theoretically it has been proved. On the other end if we come to piezopolymer (PVDF) has an excellent sensing property compared to PZT-5H.

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