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Piezoelectric Energy Harvesting using Carbon Nanotubes Reinforced Composition Beam

Prashant Pachauri

Department of Mechanical Engineering, Institute of Technology and Management, Aligarh, Uttar Pradesh-202001

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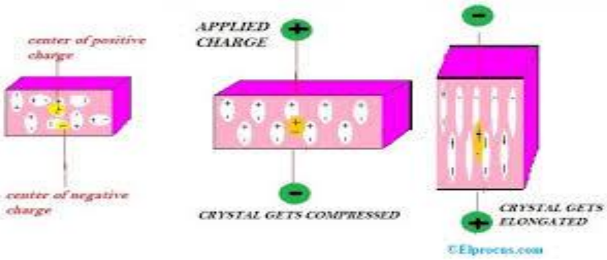
Abstract- *This paper shows the advantages of carbon nanotube's properties because it is a new class of advance composite material which help in the reusable of wasted energy in a closed system.*
This research deals with the free vibration, static, and harmonic analysis of functionally graded carbon nanotube reinforced piezoelectric beam. In that we analysis the excitation of 3g and 5g of beam.
We use carbon nanotube because of their electrical and mechanical property as well as the accessibilities in microscopic scale. Simulation result showed that the increasing in the volume fraction of carbon nanotube increases the stiffness of the beam.

key word: CNT- Carbon Nano Tube, CNTRC- Carbon Nanotube Reinforced Composite, UD- Uniformly Graded, FG- Functionally Graded, ANSYS- Analysis System.

1. INTRODUCTION:

Energy harvesting by the CNT is a very unique process for reusing the wasted energy closed by a system because all the external sources which produces the energy harvest by the CNT. Energy harvester extract and store electric charge or voltage from close environmental condition. There are many mediums by which we harvesting the energy, that are vibration, piezoelectric and CNTRC. It plays a very crucial role in industries, defence, medical, cordial reception and numerous alternative industrial sectors. There are many harvesting systems which are- pyroelectricity, piezoelectricity, photovoltaic, thermoelectricity, fuel cell, wind mill and so on. These types of process going on from ancient time to till now and play a very major role.



2. MATHEMATICAL MODELLING:

In that research, we work on 4 functionally graded CNTRC beam those are UDCNTRC, FG-X, FG-O, FG-V and done the mathematically modelling on them. Equation which we are using gives the detailed finite element formulation of cantilevered harvester of the piezoelectric energy. Final derived equation of piezoelectric cantilever energy harvester was derived by Hamilton theory and those equations are-

$$\left([\boldsymbol{M}]\{\ddot{\boldsymbol{r}}\} + [\boldsymbol{L}]\{\boldsymbol{r}\} + [\boldsymbol{l}_{\boldsymbol{\theta eff}}]\{\boldsymbol{\varphi}\}\right) = \{\boldsymbol{F_B}\}$$
$$[\boldsymbol{l}_{\boldsymbol{\theta eff}}]\{\boldsymbol{r}\} + [\boldsymbol{l}_{\boldsymbol{\varphi eff}}]\{\boldsymbol{\varphi}\} = \{\boldsymbol{Q}\}$$

3. Modelling and Analysis:

By taking care of engineering and multi physics issues, we model and analysis the beam. Closed circuit voltage and power are also calculated across the load resistances of 1kΩ, 10kΩ and 100kΩ mathematically. For modelling we fixed beam at one end and allowed to bend under applied force or load. The dynamic stain from the piezoelectric layer and creates an alternative voltage output across the electrodes which covering the layer which find the density, young modulus, poisons ratio and so on. We take ANSYS workbench for model, static and harmonic analysis for CNTRC beam at 11% and 17% fraction of volume.

Table: - Non-dimensional frequencies for 11% CNT volume fraction.

Mode no.	UD	FG-V	FG-O	FG-X
1	0.044	0.035	0.03	0.053
2	0.09	0.077	0.076	0.096
3	0.199	0.182	0.166	0.196
4	0.24	0.224	0.19	0.277
5	0.324	0.247	0.246	0.345
6	0.531	0.403	0.377	0.591

Table: - Non-dimensional frequencies for 17% CNT volume fraction.

Mode no.	UD	FG-V	FG-O	FG-X
1	0.056	0.038	0.038	0.067
2	0.119	0.104	0.093	0.123
3	0.214	0.206	0.183	0.216
4	0.311	0.236	0.224	0.336
5	0.419	0.327	0.297	0.425
6	0.67	0.531	0.425	0.684

We get first bending shape of beam mode then second and third are twisted and lateral and deformation shape.

4. Validation:

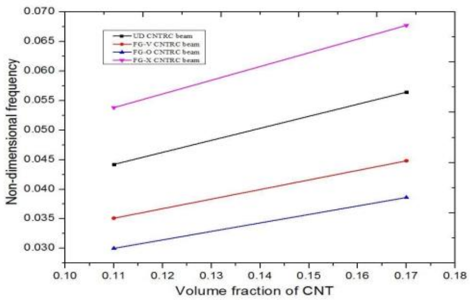
Here, we validate the effectiveness and the present model and the deflection of square plate under different - different conditions by that get accuracy in frequencies as like the frequencies given by the Zhu at al. [5]. We take FG-CNTRC plates and ANSYS workbench platform which used to model the plate for validation. This analysis performs on 11% and17% volume fraction and we analyse that the non-dimensional natural frequency is converging to reference result for the same mass fraction of CNT by increasing number of rods of CNT.

The central deflection of FG-CNTRC plate get clamped for all edges and these edges simply supported the boundary conditions.

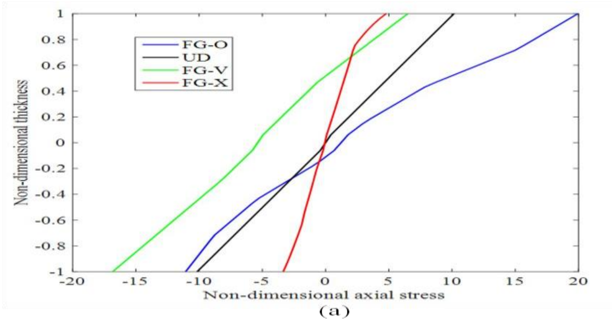
5. Results and Discussion:

Here, we determine the result of model, bending and harmonic analysis and calculating the closed voltage and power of 1kΩ, 10kΩ, 100kΩ load resistance.

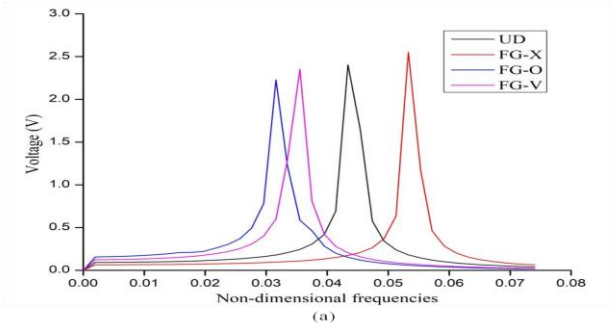
In model analysis, when we increase the fraction of volume then natural piezoelectric CNTRC beam frequency get increases. FG-X CNTRC beam has higher natural frequency than other while FG-O CNTRC beam has smaller.



In bending analysis, when we increasing the volume fraction the deformation of beam get decreases which make effect on central axial stress and shear strain and FG-V and FG-O CNTRC beam are larger as compare to



In harmonic analysis, one end is fixed while another is clamped and we found that FG-X CNTRC beam develop more voltage and FG-O voltage output is minimum.



We get maximum voltage at 100kΩ resistance for all type and maximum power at 10kΩ because resistance between 10kΩ and 100kΩ are optimum so the output power of harvester is diminished.

6. Conclusions:

Non dimensional natural frequency of beam is increased by increasing in CNTs. For FG-X CNT volume fraction increased by 6% lead to non-dimensional fundamental frequency by 26%.

Increase in 6% volume fraction give 30% decrement in non-dimensional deformation in transverse direction. FG-0 distribution has the maximum non-dimensional deformation than other.

FG-X has maximum open circuit voltage because of highest stiffness than other. FG-X volume fraction increase by 6% lead to the voltage of piezoelectric harvester by 20%.

10KΩ resistance have maximum power harvester for FG-X CNTRC beam. Power harvester increases by approximately 35% for 6% increment in FG-X CNTRC.

7. Future Scope:

By the present study, future scope is in the NCG output optimization, generate power storage for design the converting circuit and find the energy storage system, another while FG-X have least deformation.

Bi-morph piezoelectric FG CNTRC beam and the value of resistance can be optimized to harvest maximum power.

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