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Finite Element Modelling of Piezoelectric Harvesting Elements on Carbon Fibre Composite Structures for Vibration Energy Harvesting

D. El Fadlaoui[1], B. Boubeker[2], M. Idiri[3]
[1]*Laboratory of Engineering and Materials (LIMAT), Faculty of Science Ben M'Sik, Hassan II University, Casablanca, Morocco.*

Abstract: This paper presents a finite element model (FEM) developed for a wide range in aerospace, automotive and renewable energy application, such as powering sensor for structural health monitoring and wireless sensor for electronic sectors .Using ANSYS to model and simulate a piezoelectric (PZT) energy harvesting on carbon fibre composite structures (CFCS) in order embed energy harvesting capability onto the mechanical structure. A computational program is applied for investigating the static and dynamic behaviour of CFRP plates with piezoelectric layers symmetrically bonded to the top and bottom surfaces. Indeed, a set of numerical simulation is carried out and the results are compared with those of static, isotropic model and the harmonic response without the load resistor and static, anisotropic model and the harmonic response with the load resistor. Numerical results demonstrate that the amount of change seen in both model and harmonic response deformation with and without load resistor.

Keywords: FEM, PZT, CFCS, ANSYS, Harmonic Response

I. INTRODUCTION

Energy harvesting based on piezoelectric technology is an attractive research area that has been developed over the last decades for the realisation of autonomous and self-powered electronic devices. Indeed, a piezoelectric effect is responsible for the materials ability to function as a sensor / actuator, by transforming ambient vibration into wireless sensing power for structural health monitoring.

II. NUMERICAL SIMULATION

Finite element (FE) modelling was used to investigate the benefits of the auxetic region on the harvested power.Finite element methods were used for modelling piezoelectric sensors and actuators. In the presents study The FE model, developed in ANSYS

A. Specimen Details

In this study a nominal design of a piezoelectric harvesting elements were laid up with the carbon fibre/epoxy composite with the size of 82.4mm*26.7mm*20mm with and without a resistor were made using aluminium alloy as shown by Fig.1
The material properties taken into account for the present numerical analysis is listed in Table 1, and table2.

Table.1:Piezo Material Isotropic > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
62000	0.3	51667	23846

Table.2:Aluminum Alloy > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
71000	0.33	69608	26692

The present study deals with the finite element simulation CFCS with Harmonic responses were studied with the Frequency range from 0 to 100 HZ with 40 sub steps. The present analysis has been modelled and simulated in Accordance to Table 3. Anisotropic material properties table 4 were applied.

Table .3: Epoxy Carbon UD (230 GPa) Wet > Orthotropic Elasticity

Young's Modulus X direction MPa	Young's Modulus Y direction MPa	Young's Modulus Z direction MPa	Poisson's Ratio XY	Poisson's Ratio YZ	Poisson's Ratio XZ	Shear Modulus XY MPa	Shear Modulus YZ MPa	Shear Modulus XZ MPa
1.2334e+005	7780	7780	0.27	0.42	0.27	5000	3080	5000

Table.4: Piezo Material Anisotropic > Anisotropic Elasticity

D[*,1] MPa	D[*,2] MPa	D[*,3] MPa	D[*,4] MPa	D[*,5] MPa	D[*,6] MPa
1.468e+005	81090	81050	-	-	-
81090	1.4688e+005	81050	-	-	-
81050	81050	1.3171e+005	-	-	-
0	0	0	31350	-	-
0	0	0	0	31350	-
0	0	0	0	0	32890

III. FE MODELLING RESULTS AND DISCUSSIONS

The finite element model of the PZT on CFRP Without load resistor and PZT on CFCS With load resistor (W/resistor) are represented in Fig. 1.

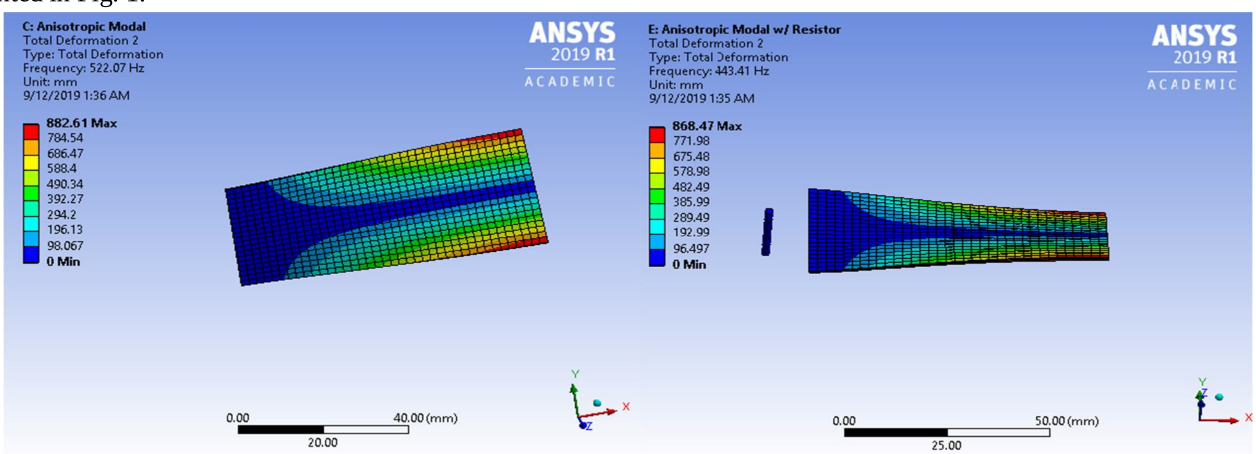

Fig. 1 (a) Deformation for PZT Anisotropic Model; (b) Deformation for PZT Anisotropic Model W/Resistor

The present study, the numerical software package ANSYS®19 R1 is applied for study the effects of harmonic Response for piezoelectric materials with and without load resistor and represented in Fig (2-4).

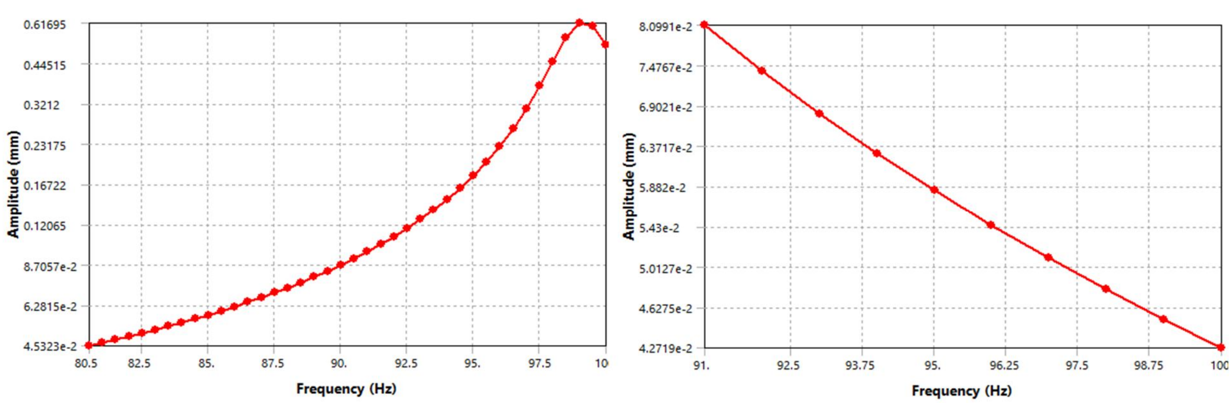

Fig. 2 a) Displacement of Harmonic response for PZT; (b) Displacement of harmonic response for PZT W/Resistor

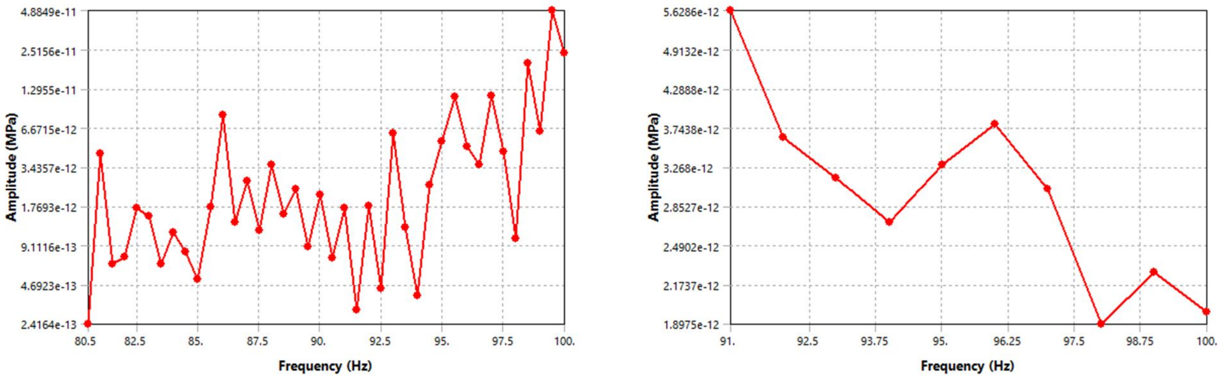

Fig. 3 (a)Normal Stress for PZT; (b) Normal Stress for PZT Anisotropic W/Resistor

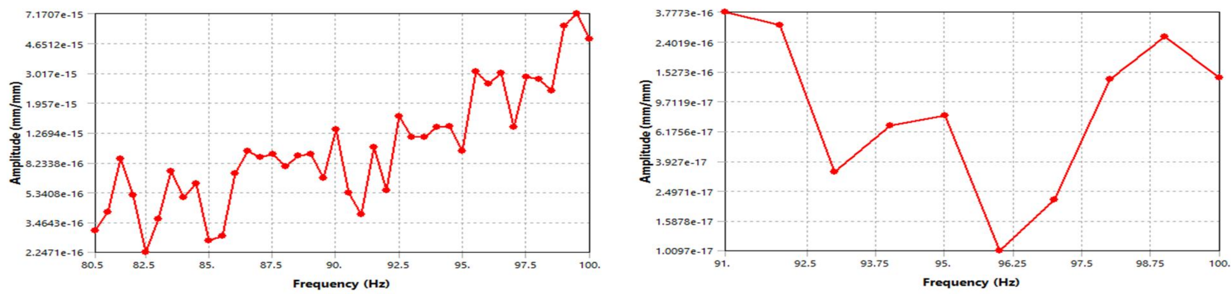

Fig. 4 (a) Elastic Strain for PZT; (b) Elastic Strain for PZT Anisotropic W/Resistor

In this study, The results from piezoelectric element on CFCS with and without load resistor showed that
The Displacement of Harmonic response for PZT increase while Displacement of Harmonic response for PZT W/Resistor decrease Fig.2 In both normal stress and elastic strain it seen change between harmonic response for PZT with and without load resistor fig(3-4) .

IV. CONCLUSION

The results obtained from FEM showns that Piezoelectric harvesting elements on Carbon Fibre Composite structures for Vibration Energy Harvesting with and without load resistor has been modelled and simulated with finite element capabilities.
A comparative study of the finite elements (ANSYS) for piezoelectric smart material with and without load resistor has been carried out.

1) *Word Count:* 906
2) *Submitting Author:* D. EL FADLAOUI ; Tel.: +44 (0)7383096613; E-mail: Douniaaelfadlaoui@gmail.com

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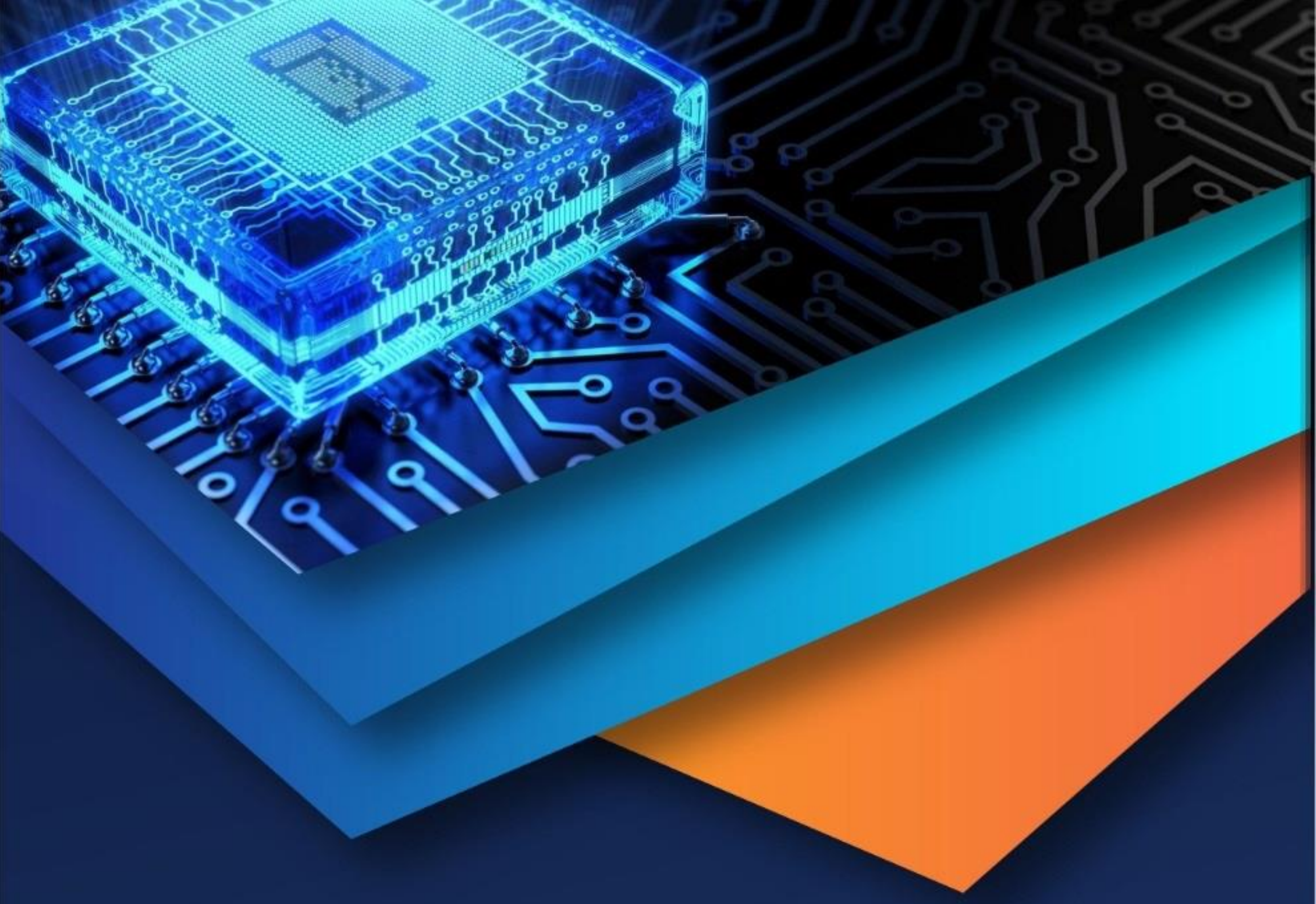

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