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Natural Frequency of CNT Reinforced Composites Using Finite Element Method

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Abstract: Researchers in both industry and academia are taking a keen interest in developing advanced nanocomposites with multifunctional features. Carbon nanotubes (CNTs) are unique nanostructured materials which possess extraordinary physical and mechanical properties. It is their remarkable properties that bring interest in using CNTs as filler in polymeric matrix to get ultra-light structural materials, which are referred to as carbon nanotube reinforced polymer composites (CNTRPs).In thepresentpaper,thesimulationofthe vibrational responsesofcarbonnanotubes reinforced epoxy composites has been done by using Finite Element Method (FEM).The natural frequency and the corresponding modes at different boundary (simply supported, Fixed-Fixed supports, one end fixed support) conditions are investigated.Also the authors analysed the composite for the same end conditions by providing a regular shaped cuts like cylindrical, square, triangular, rectangular at the centre of the plate. The mechanical properties have been evaluated for different volume fractions of CNTs.The outcomes of this study are in good agreement with those reported available in the literature earlier.
Keywords:Nano Composites, Carbon NanoTube, Natural frequency , FEM analysis.

I. INTRODUCTION

Carbon nanotubes discovery was first identified in the mid 1980s, as Smalley and co-workers at Rice University developed the chemistry of fullerenes [1]. The fullerenes are cage-likegeometric structures of carbon atoms that are composed of hexagonal and pentagonal faces. A few years later, their discovery led to the synthesis of carbon nanotubes. Finally, Carbon nanotubes were discovered in 1991 by Iijima [2].

A single-walled carbon nanotube (SWCNT) can be thought of as a single graphite sheet rolled into a tube and capped by two hemisphere fullerenes.During these past years in the field of innovation and engineering, carbon nanotubes (CNTs) have attracted much research attention. Especially they are predicted as ideal reinforcement for manufacturing of aircrafts and sports goods, duetotheirhighaspectratio,strength,elasticmodulusand low density [3,4]. For instance,CNTs have shown to possess the highest elastic modulus (>1 TPa) in axial direction among all the materials found in the nature[5].There is much work done in investigating these properties of SWCNT.From the latest researches it is found that the Tensile strength of nanotubes can be up to 150 GPa, which is around 10-50 times higher than the steels of highest ultimate strength.Also there were many reports regarding how much effort has so far been rendered to the study of the various aspects of nanotubes such as buckling, mechanical, chemical,electrical and electrsonic, properties [6-8]. Researchers have concentrated their work on the utilization of such effective materialsfor macroscopic (and microscopic) applications. One of the best promising application is CNT-based reinforced composites or simply Nano based composites. CNTs have been observed to tremendouslychange the properties of polymer composites[9].Considering mechanical properties, the elasticmodulus of a polymer is seen to increase by addition of CNTs. Xu et al. [10] obtained about 20% increase inelastic modulus of epoxy resin by the addition of 0.1% CNTs as fibre. Approximately 100% increase in elastic modulus was obtained by addition of only 1.0% CNTs [11]. Other important mechanical properties such as toughness have also been observed to increase by CNT addition [12]. However, less attention has been paid to thevibrational characteristic of nanotubes.This paper gives a clear idea about those untold properties of vibrational behaviour of the SWCNT.Due to the difficulties in experimental characterizationof nanotubes, computer simulation has been regarded as a powerful tool for modelling the SWCNT,also the powerful tool thus incorporated in this study is Finite Element Method Software package, ANSYS.

II. FINITE ELEMENT MODELLING APPROACH OF NANO BASED COMPOSITE:

The effective material properties for CNT based nanocomposites have been evaluated for different volume fraction of CNT's. Circular RVEs are studied with long CNTs under axial load. The Elastic properties of composites are evaluated effectively by adopting Representative Volume Element (RVE) that consist of a single spherical particle surrounded by matrix material and a One-eighth portion is considered for analysis.

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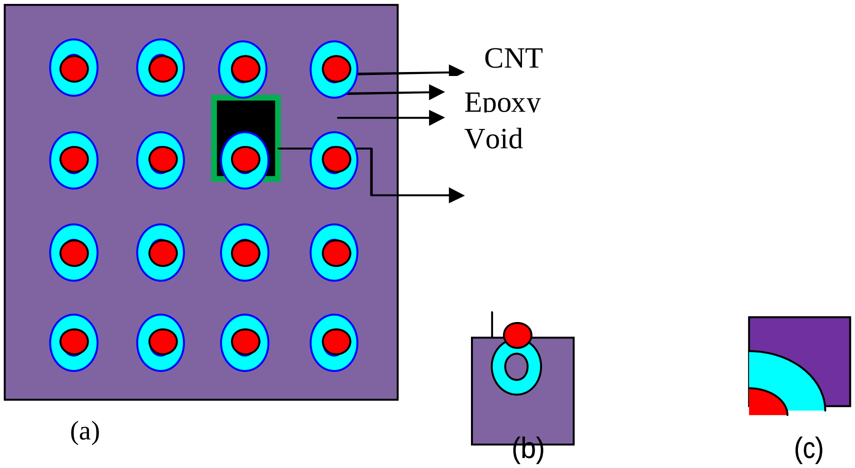

Fig.1. (a)Uniform distribution of spherical particles in a matrix (b)Isolated unit cell (c) one-eigth model

The length of the CNT=10nm, Inner Diameter of the CNT= 5nm and outer diameter of the CNT is 7.5 nm. With these geometrical dimensions and varying the volume fraction of CNT, the dimensions of Representative Volume Element is obtained. Due to symmetry of the RVE in terms of geometry, loading and boundary conditions, one eighth portion of the RVE is considered for the analysis. While analysing the properties of CNT reinforced composite, the Young's modulus for the CNT is taken as 1000 GPa and Poisson's ratio is 0.3. The Young's modulus for the epoxy resin is taken as 3.5 GPa and Poisson's ratio is 0.3 whereas for void the properties are assumed some negligible value.

The CNT volume fraction is varied from 0.1% to 0.3%. This is primarily assumptedthatnanocomposites will be used in such a way that the tubesare oriented along the direction of load. Since the strength is greatly reduced in the lateral direction, the analysis is performed only for axial load. The modelling and meshing of the nano based composite is done in ANSYS by taking the element type as Solid 20 node 95. The solid model of matrix, fibre and 0.1% CNT is shown in Fig. 2(a). The meshed model with 0.2% CNT is shown in Fig. 2 (b).

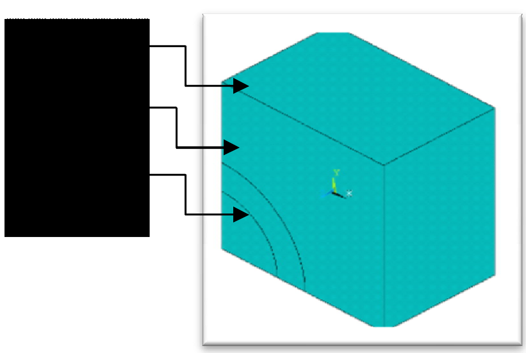

Fig.2.(a).Solid model with 0.1% CNT

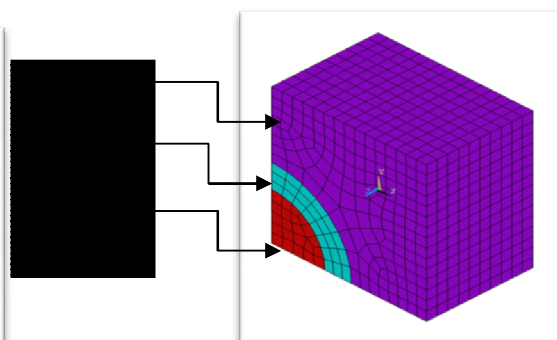

Fig.2.(b).Meshed model with 0.2% CNT

III. BOUNDARY AND LOADING CONDITIONS:

The simulation is executed for thedifferent volume fractions by applying , the following symmetric boundary conditions are used.
At x = 0, Ux = 0; At y = 0, Uy = 0; At z = 0, Uz = 0.
In addition, the opposite faces of the FE model is applied with multi-point constraints.
Boundary conditions are imposed on the finite element model in such a way that the model should act as a part of the whole array of composite materials. A uniform Pressure load of 1 MPa is applied to the CNT direction to obtain a Uni-axial state of stress that facilitates the usage of simple hook's law for predicting Young's modulus of resulting composite specimen.The applied load can be seen in the Fig.3.The results are thus obtained for the 3 weight percentages accordingly after the successful simulation in ANSYS.The results are shown below in the Fig.4.

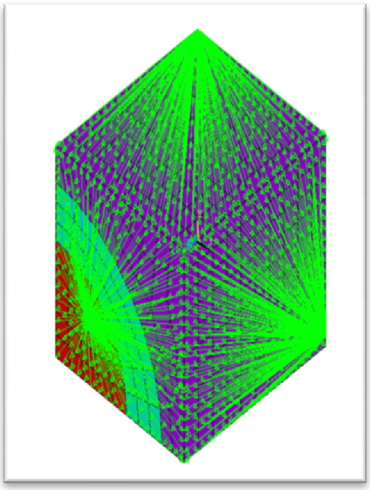

Fig.3.Loaded model with 0.3% CNT

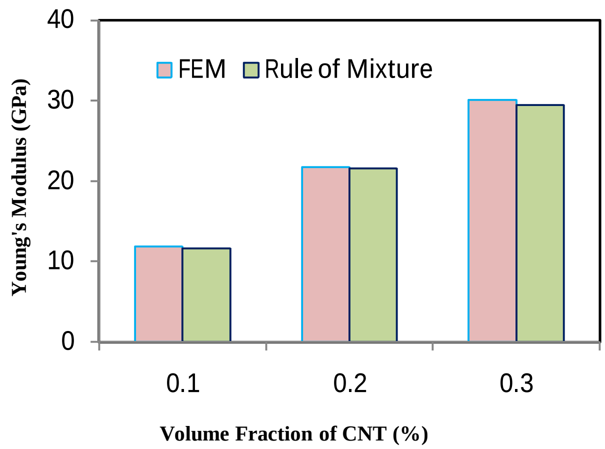

Fig.4. Variation of Young's modulus with CNT Volume Fraction

Fig.4. shows the variation of longitudinal Young's modulus with CNT volume fraction. By reinforcing the CNT's in epoxy matrix, the load bearing capacity is increasing which is observed from the CNT aligned-direction,thus obtained values of deflection are utilised for calculating respective values of Young's modulus and Poisson's ratio.

IV. VIBRATION ANALYSIS

Now the data that is obtained from the previous results, (Young's Modulus and Poisson's ratio) are utilised to carry out the vibrational analysis .The density of the composite is evaluated by the Rule of Mixture, say that the density of the composite is the algebraic sum of the individual densities of the CNT and matrixconstituents.Then the vibrational composite is modelled according to the ASTM standards say length and breadth are 100mm each and the thickness is 10mm.The modelled object is also meshed and is clearly observed in the Fig.5

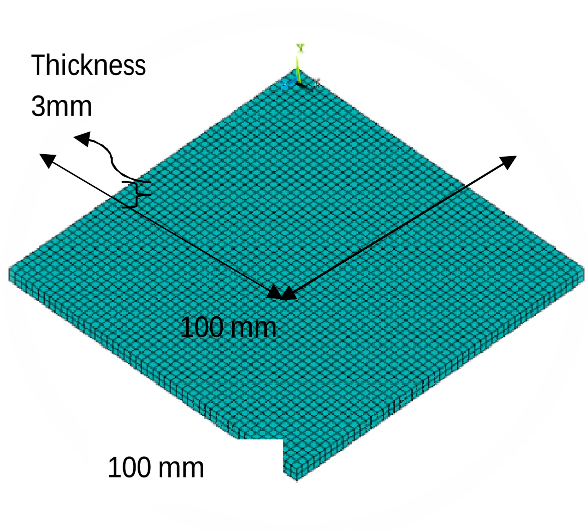

Fig.5.Modelled and meshed 0.1% CNT

The modelled CNT is new analysed for different end conditions say Simply supported, Cantilever, All edges Fixed, Two parallel edges Fixed. The figures of all 4 types of loading on the composite are seen in Fig.6.

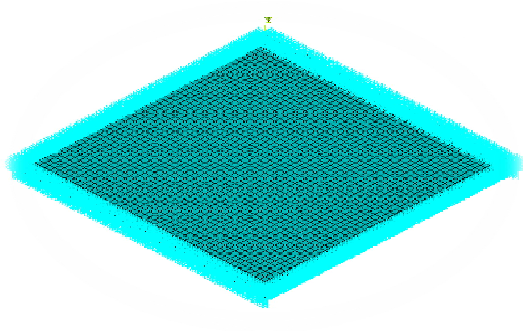

Fig6.(a). Simply supported 0.1%CNT Composite

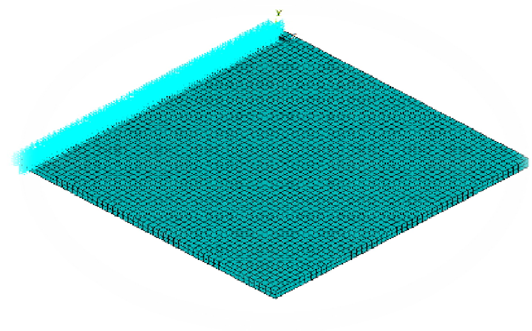

Fig.6.(b).Cantilever end 0.2%CNT Composite

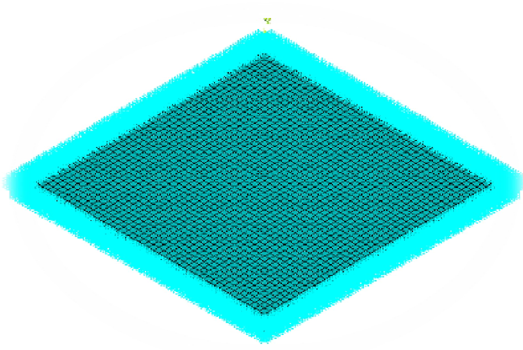

Fig.6.(c).All edges fixed conditioned 0.2%CNT composite

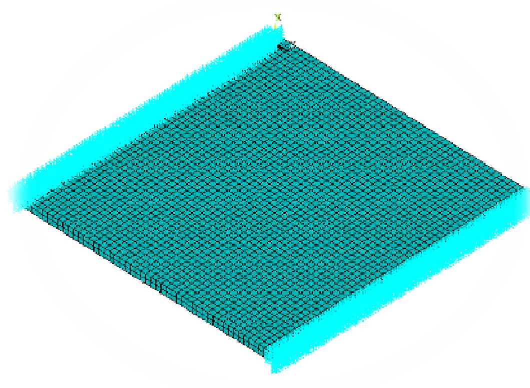

Fig.6.(d).Two edges fixed conditioned 0.3%CNT Composite

The end conditions are applied to evaluate the first five modes of natural frequency. The obtained values are seen in the graph Fig.7. The 5 modes of frequency are obtained for all end conditions by effectively applying the boundary conditions and thus the modal analysis has given out the frequency. From the Fig.7, it is observed that the natural frequency is high for all sides fixed boundary conditions. because, fixing the all sides increases the stiffness of the composite plate, as the natural frequency is directly proportional to the stiffness, the natural frequency increases. Now the same analysis procedure is followed for the composite plates which are provided with regular cuts like Circularcut, Rectangle cut, Square cut,Triangle cut. Here the removed part of the composite material is maintain at same volume. The modelled such plates are shown below in the Fig.8.

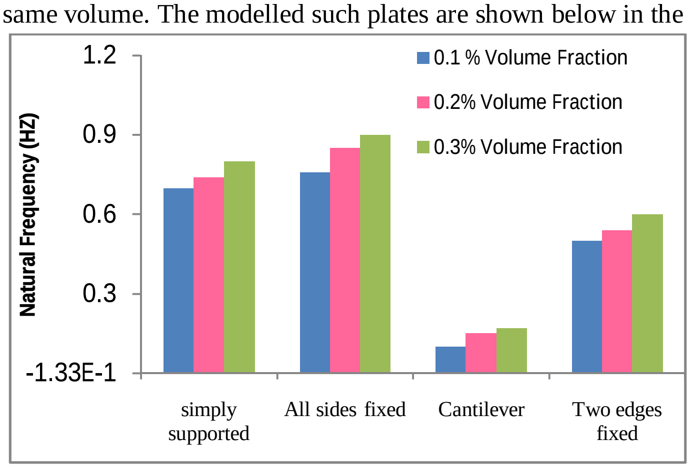

Fig.7.Result graph of natural frequency for all end conditions

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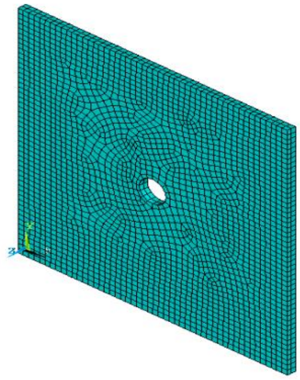

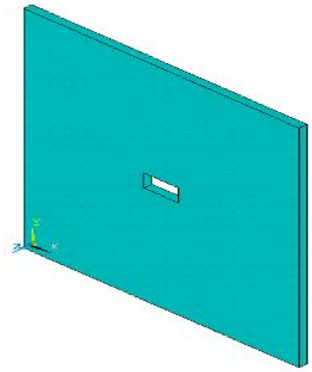

Fig.8.(b).Rectangular cut model for 0.1%CNT
Fig.8.(a) Circularr cut mode for 0.2%CNT

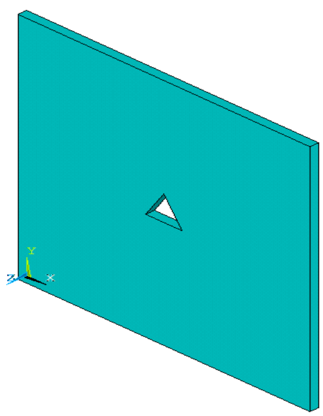

Fig.8.(c).Triangle cut mode for 0.3%CNT

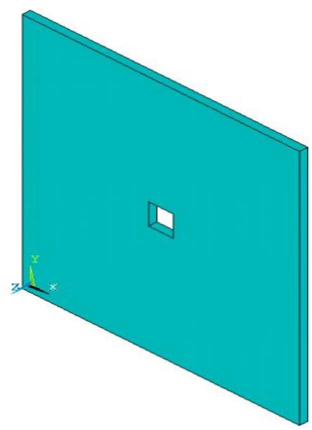

Fig.8.(d).Square cut mode for 0.1% CNT

The ANSYS package facilitates to simulate the vibrational analysis for the different weight percentages nano based composites and for different end conditions for provided regular shaped cuts.The results obtained for the different end conditions and for shaped cuts are seen below Fig.9. From the Fig. 9, it is observed that, the shape of the cut at the centre of the plate has insignificant effect on the natural frequency. It is understood that, maintaining any shape volume of cut of any considerable shape has not affected the natural frequency.

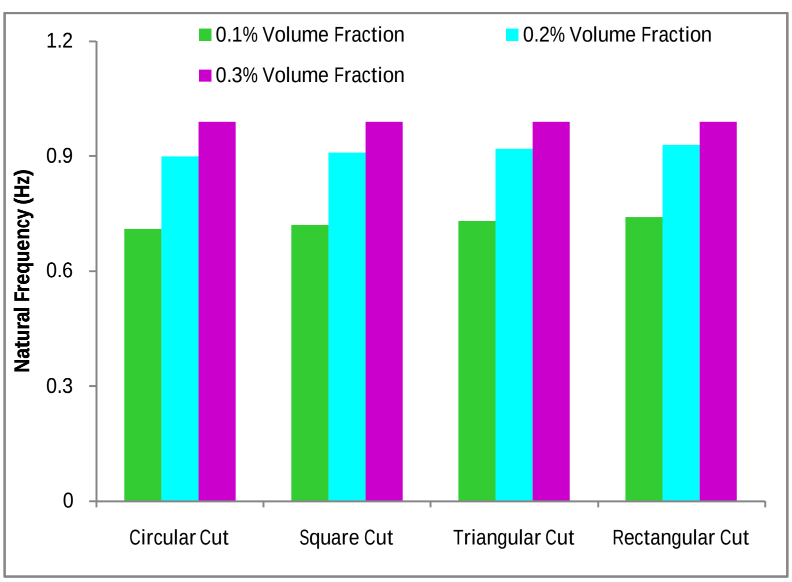

Fig.9.(a) Simply supported result for all shaped cuts

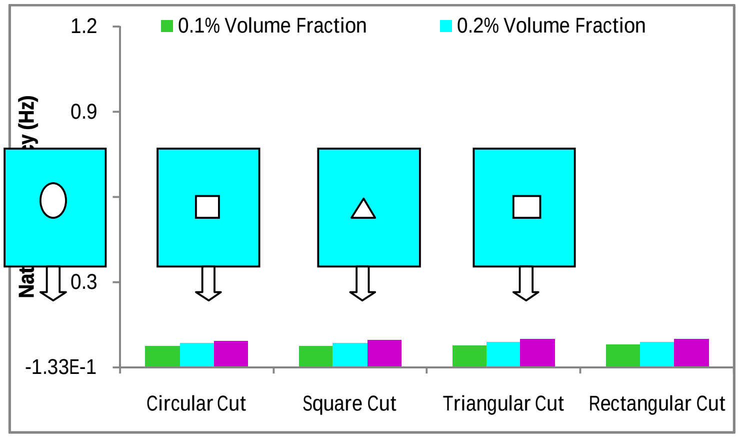

Fig.9.(b).Cantilever end result for all shaped cuts

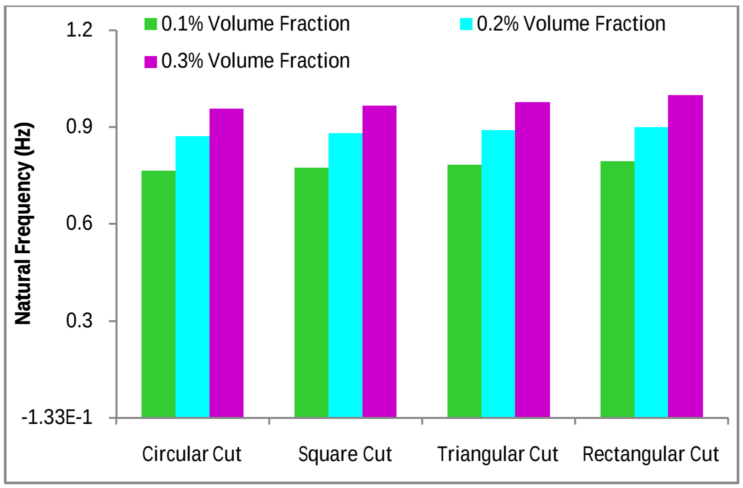

Fig.9.(c).All end fixed result for all shaped cuts

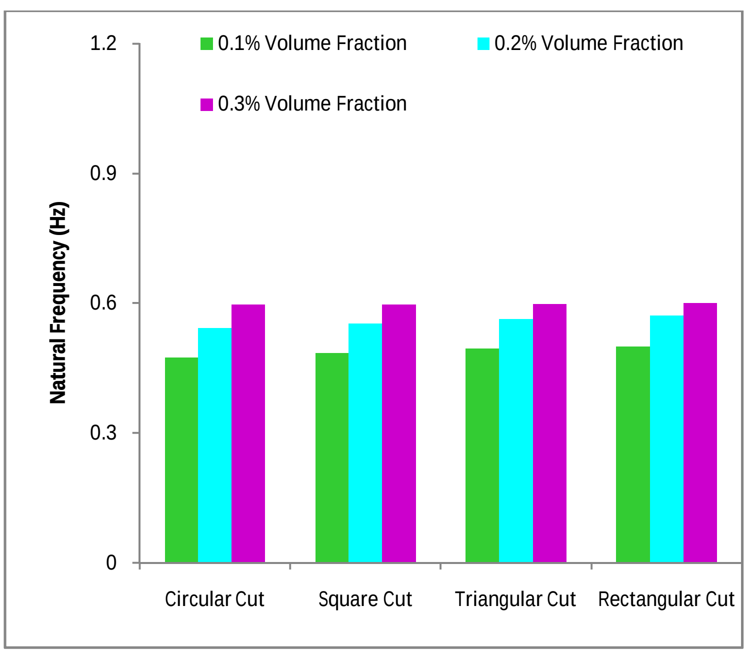

Fig.9.(d).Two edges end fixed result for all shaped cuts

V. CONCLUSIONS

The Finite element method is used to estimate the elastic modulus and natural frequency of the CNT reinforced composite material. The following conclusions are obtained from the present work.

Young's modulus of the epoxy matrix will be enhanced with the minimum contribution of Carbon Nano Tube reinforcement.

Natural Frequency of the All sides Clamped CNT reinforced Composite Plate shows Good frequency among all other end conditions considered for the study.

The composite Plate with different shapes of the cuts have insignificant effect on the natural frequency of the composite material.

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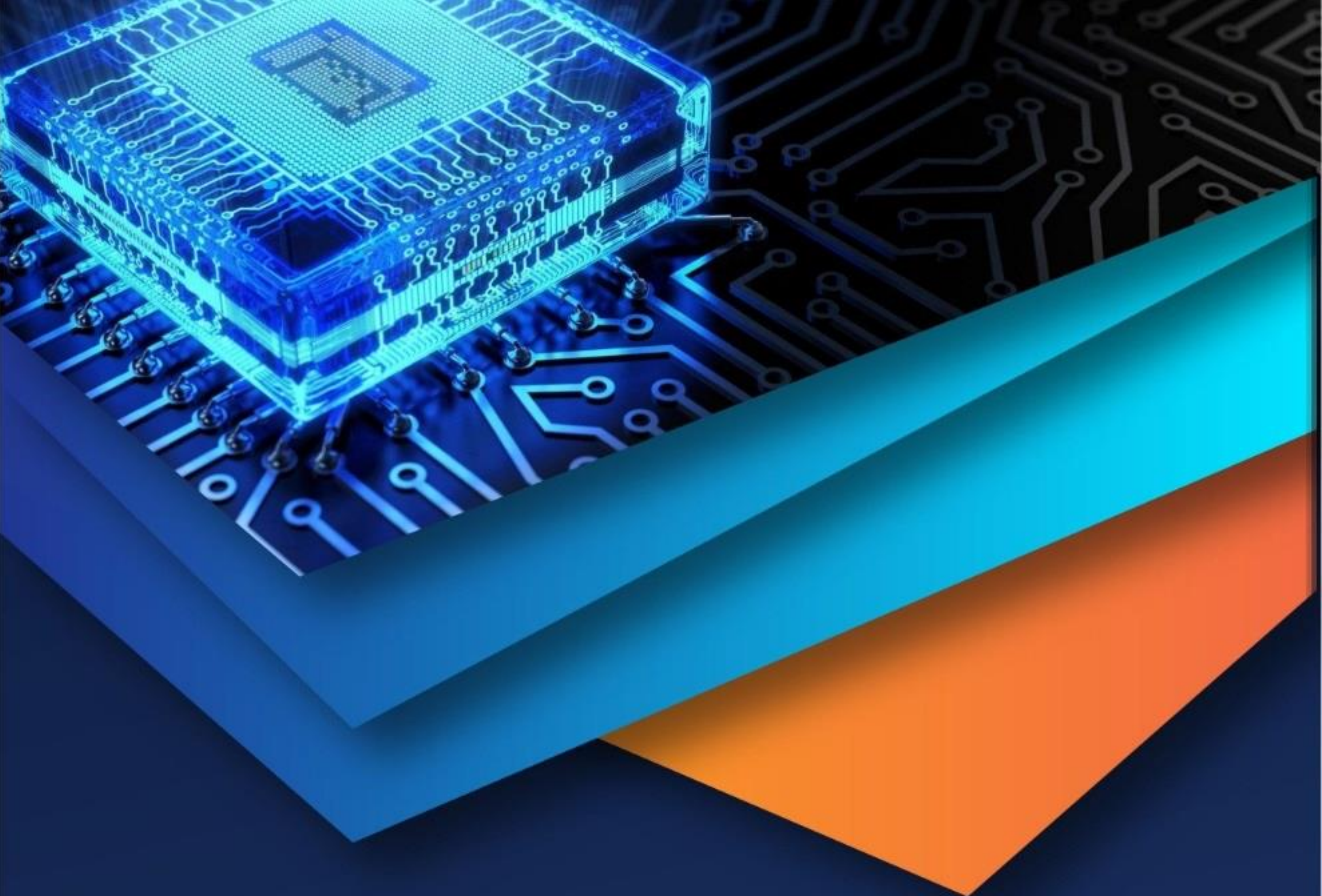

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