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Experimental Analysis of Fiber Reinforced Composite Beam with Crack by varying Process Parameters

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Abstract: In the recent decades, fiber reinforced composite materials are being used more frequently in many different engineering applications. In engineering design averting failure of composite material system has been a vital concern. Composite are subjected to various types of damage, mostly cracks and delamination. The presence of crack causes a variation in stiffness and it also affects the mechanical behaviour of entire structure. Cracks are caused by fatigue under service conditions as a consequence of low fatigue strength. Measurement of natural frequency can be taken as a tool to identify the presence of cracks which are propagated due to fluctuating stress conditions. In the present work an attempt has been made to find the natural frequencies of fiber reinforced composite cantilever beams with and without presence of a transverse surface crack. The effect of an open crack on the Natural frequencies of the cantilever beam subjected to free vibration is analysed and the results obtained from the numerical method i.e. finite element method (FEM) and the experimental method are compared. E-Glass fiber reinforced composite beams with epoxy resin having a volume fraction of 40% with 10% fly ash have been casted by hand lay-up method and are used for determination of natural frequencies of beams. The free vibration study is carried out by Vibration Shaker. It is concluded that outcomes acquired from test have an excellent agreement with the outcomes obtained from FEM.
Keywords: Natural frequency, transverse crack, E-Glass fiber, Fly ash, FEM

I. INTRODUCTION

In the recent years, fiber reinforced composite materials are being used more frequently in many different engineering applications. The automobile, aerospace, naval, and civil industries all utilization composite materials here and there. Composite materials are picking up popularity as a result of high quality, low weight, protection from erosion, impact resistance, and high weariness quality. Different focal points incorporate simplicity of creation, adaptability in structure, and variable material properties to meet practically any application. Structural damage acknowledgment has increased expanding pondering from the logical society since sudden significant risks, most with human misfortunes, have been accounted for. Aircraft crashes and the catastrophic bridge failures are a few illustrations. The cracks can be present in structures due to their low fatigue strengths or due to the manufacturing processes. These cracks intensity will grow over time, as the load reversals continue, and may reach a point where they pose a threat to the integrity of the structure. Therefore, all such structures must be carefully kept up and all the more for the most part, SHM signifies a solid framework with the capacity to identify and decipher unfavorable "change" in a structure because of damage or typical activity (Ramanamurty 2008).

Douka et al. [1] have exhibited a technique for deciding the location and crack depth in double cracked beam. For identifing the crack, variation in natural frequency and anti-resonance properties are used by them. Tian et al. [2] have used mid frequency flexural wave to detect the presence of crack and its position in a cracked beam. Ostachowicz et al. [3] have presented a method assuming an open and closed crack with triangular disk finite elements, he has examined the forced vibrations of the beam, the impacts of the crack areas and sizes on the vibration behavior and discussed about a reason for crack identification. Ayre et al. [4] have developed a method for calculating the natural frequencies of continuous beams of uniform span length by vibration analysis. Bollinger et al. [5] have presented a method for analysis and prediction of the static and dynamic behavior of machine tool spindle systems using finite difference technique. Mercer et al. [6] have developed a transfer matrix method for the prediction of natural frequencies and normal modes of a row of skin-stringer panels. They have also presented few examples. Miles [7] has carried out analysis of beams on many supports using vibration parameters. Lin et al. [8] have briefly surveyed the use of transfer matrix method for analyzing the dynamic behavior of beam structures. Chun [9] has considered the free vibration of a beam hinged at one end by a rotational spring (with a same spring constant) and the other end free. Murat Kisa [10] has developed new concept of theoretical analysis of composite cantilever beam under the free vibration with open cracks. KausharH.Borad et al [11] has presented Fatigue life and depth of crack was detected in cantilever beam using frequency based method. Oruganti et al [12] Deviation mode shape analysis and curvature mode shape analysis were used to detect the damage in composite beam.

II. THEORETICAL ANALYSIS

E-Glass fiber reinforced composite beams of dimensions 300mm x 50mm x 7mm with volume fraction of 40% with Flyash volume fraction of 10% are casted by hand layup method. The beams are then subjected to free vibration for cantilever boundary condition by Vibration shaker. A composite is a structural material that comprises of at least two constituents that are consolidated at a macro level and are not dissolvable in one another. One constituent is known as the reinforcement and the one in which it is implanted is known as the matrix. The volume fraction of a fiber reinforced composite is defined as the ratio of volume of fiber to volume of composite

$$V_f = \frac{W_f}{\rho_f} / \left(\frac{W_f}{\rho_f} + \frac{W_m}{\rho_m}\right) \text{ ------ (1),}$$

$$\rho_c = \rho_f V_f + \rho_m V_m \text{ ------------------(2)}$$

Where V_f = Volume fraction of fiber, V_m= Volume fraction of the matrix, W_f = Weight of fiber, ρ_f = Density of fiber, W_m = Weight of the matrix, ρ_m = Density of the matrix, ρ_c= Density of composite

$$E_1 = E_f V_f + E_m V_m \text{ ------------------ (3)}$$

Where E_1= Longitudinal Young's Modulus, E_f = Young's Modulus of Fiber, V_f= Volume fraction of Fiber, E_m = Young's modulus of Matrix, V_m = Volume fraction of Matrix.

$$\frac{1}{E_2} = \frac{V_f}{E_f} + \frac{V_m}{E_m} \text{ --------(4)}$$

Where E_2 = Transverse Young's Modulus
$E_2 = E_3$, where E_3 = Transverse Young's Modulus in another transverse direction.

Table 2.1 Properties of E-Glass Fiber Reinforced Composite Beam for 40% Volume Fraction with 10% Flyash.

E_x (GPa)	E_y (GPa)	E_z (MPa)	G_{xy} (GPa)	G_{yz} (GPa)	G_{xz}(GPa)	υ_{xy}	υ_{yz}	υ_{xz}
40.722	17.073	17.073	22.279	20.5	22.2	0.29222	0.12251	0.12251

III. EXPERIMENTAL METHODOLOGY

The fiber reinforced composite beams consists of E-glass fiber reinforced in epoxy resin. The sequence of arrangement of E-glass fiber in each layer is one of the assessment parameters. These specimens were cast using hand layup technique as shown in figure. Open mould was used for casing of flat composite plate. The manufacture of composite was completed by putting fluid resin alongside the reinforcing fibers on the completed surface of the molud. The proportion of fiber and matrix, fly ash was taken 40:50:10 percent by weight. The matrix composed of gel coat made up of epoxy and 13% hardener HY150. Six layers of E-Glass fibers were used for preparation of the composite laminate.

The casting of specimen was started with the deposition of gel coat on the plastic sheet placed over the open mould, with help of a brush. The releasing agent was sprayed on the plastic sheet before application of gelcoat. The bottom most layer of reinforcement was provided by placing the fiber on the gel coat. Steel rollers were used to confirm that no air bubble was entrapped after which the next layer of E-Glass fiber which were cut earlier cut to required size were put on the gel coat. The top most gel coat was laid at last and another plastic sheet sprayed with releasing agent. The whole arrangement was kept under a heavy flat metal rigid platform in normal room conditions for at least 24 hours for proper compression. The plate so obtained then moved for cutting it in to beams of required size. The process is shown in Fig.

The physical properties of fabricated composite beams such as density and thickness were measured. The weights of specimens were measured using digital weighing balance. A transverse crack of required 4mm, 3mm, 2mm depth was generated using small hacksaw at desired position say at 30mm, 150mm, 225mm distance from fixed end. Vibration test was conducted using vibration shaker. The process of finding out these natural frequencies was repeated by varying these above parameters. Similarly by changing the position of crack the entire procedure was repeated for different crack depths at various required crack locations on the beam from fixed end.

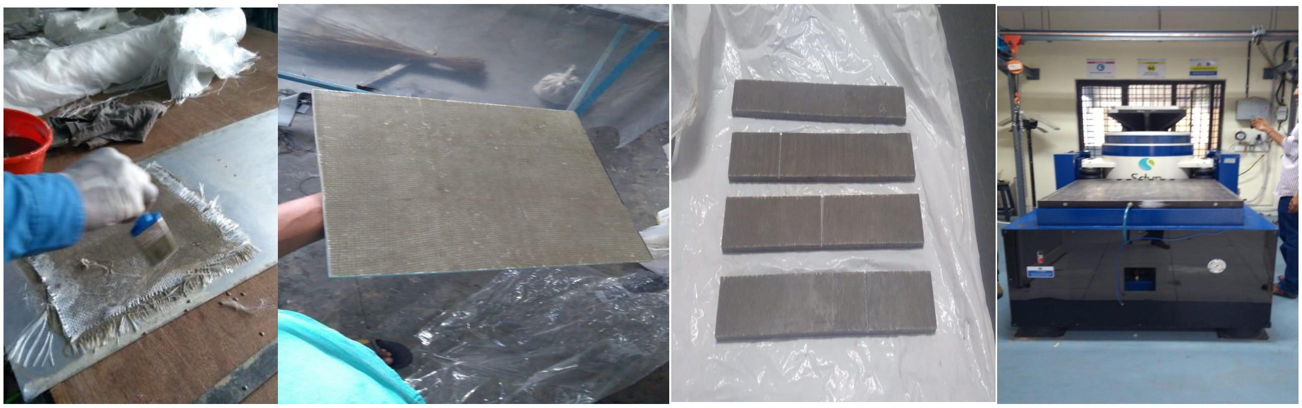

Fig.3.1 Fabrication Process of E-Glass Fiber

IV. SIMULATION USING ANSYS WORKBENCH

Created a beam type model in Uni Graphics (NX 11) with dimensions 300 × 50 × 7 mm .And exported as .prt (Part File).then imported in ANSYS Workbench 16.0V. In Pre Processor select Element type (ET46) and material properties are defined with the help of material model menu. Orthotropic material properties have been considered and the values of various input parameters are given. Now the process of fine meshing is carried out by using mesh tool and meshed the beam with 2 mm element size (Hex Mesh). The necessary boundary conditions are imposed to form the cantilever composite beam by arresting all degrees of freedom at on end cross section of the beam. In solution stage the modal analysis type is chosen and Blocklanczos method is used for natural frequency extraction. The procedure is carried at various crack depths for different crack locations along the beam.

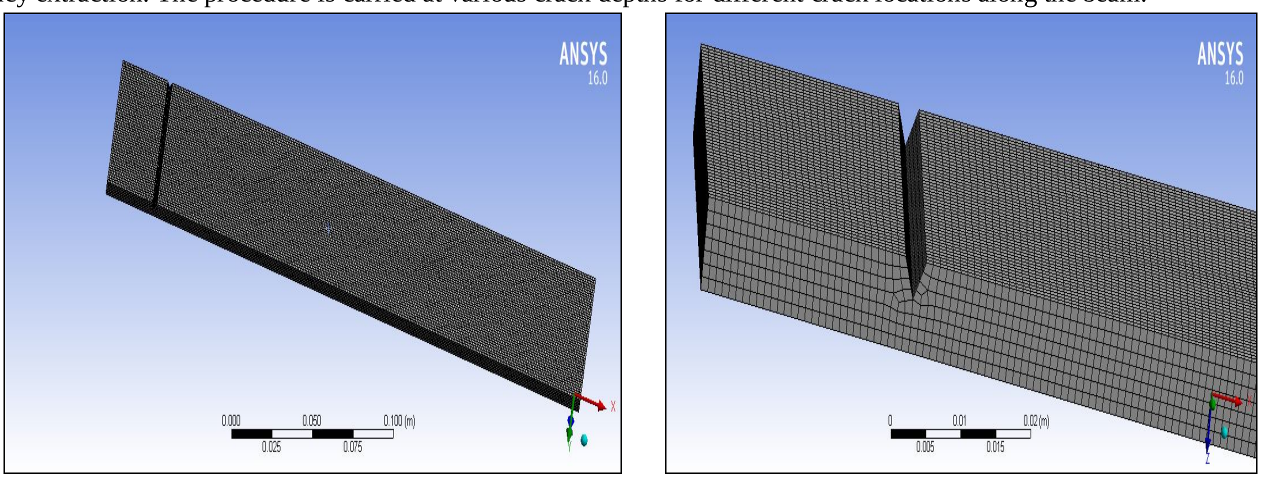

Fig.4.1 Composite beam meshed (Hexahedron) with 2mm element size

V. EXPERIMENTAL RESULTS

Dynamic analysis of E-Glass fiber reinforced composite beams of dimensions 300mmx50mmx6mm have been considered for analysis. The natural frequencies of these beams have been found for cantilever beam boundary condition without and with a transverse surface crack. The process is carried out by both experimentation and simulation using ANSYS16.2. The process is repeated for various depths at different locations along the beam length. The results obtained are shown in graphs. The variation of natural frequency with Depth of cut (DoC) at different Crack Positions is shown in Fig. It is observed that as the depth of the crack increases the natural frequency decreases. Similarly as the position of the crack changes from fixed end the natural frequency increases for the same crack depth. These variations are shown in Fig. These variations in natural frequencies are due to change in the stiffness of the composite beams due to presence of the crack, its intensity and location. A careful study of these changes supports to identify the presence of the cracks in structural members without disengaging the member from the system. The results from the experimental and numerical methods are compared in the below graphs.

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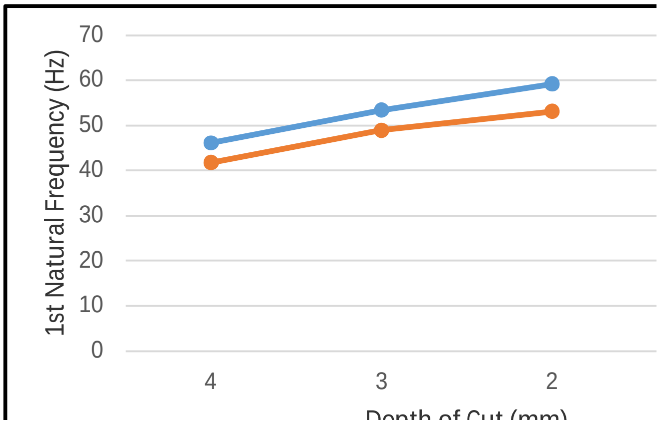

Fig.5.1 1st Frequency vs DoC, crack at 30mm from fixed end.

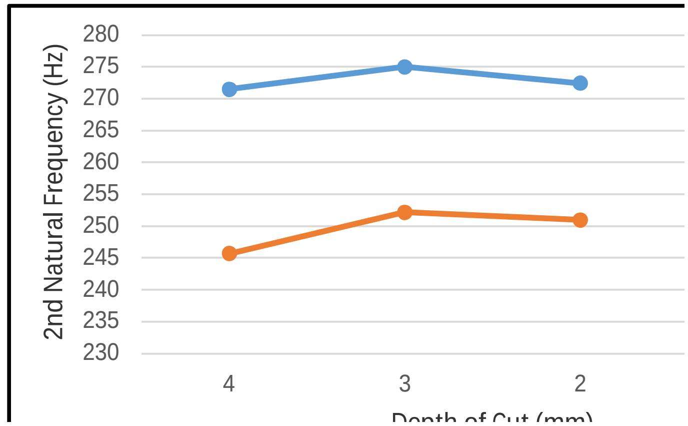

Fig.5.2 2nd Frequency vs DoC, crack at 30mm from fixed end.

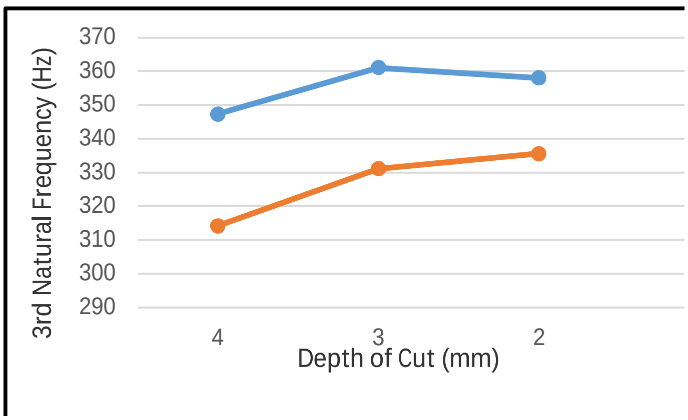

Fig.5.3 3rd Frequency vs DoC, crack at 30mm from fixed end

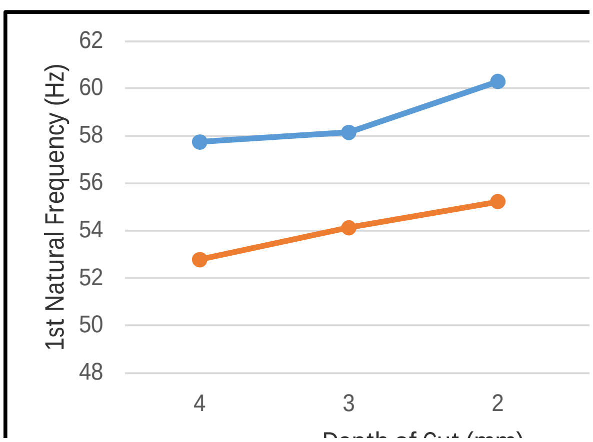

Fig.5.4 1st Frequency vs DoC, crack at 150mm from fixed end.

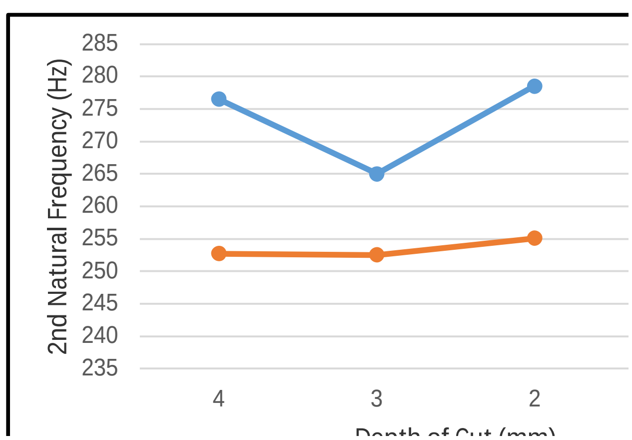

Fig.5.5 2nd Frequency vs DoC, crack at 150mm from fixed end

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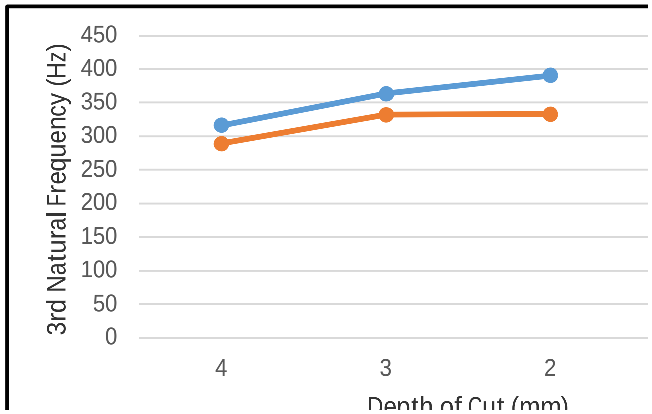

Fig.5.6 3rd Frequency vs DoC, crack at 150mm from fixed end

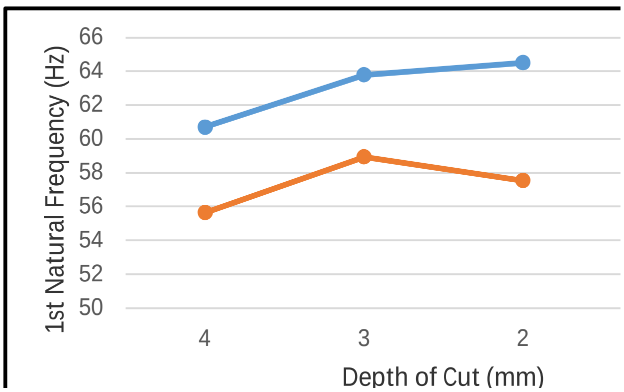

Fig.5.7 1st Frequency vs DoC, crack at 150mm from fixed end

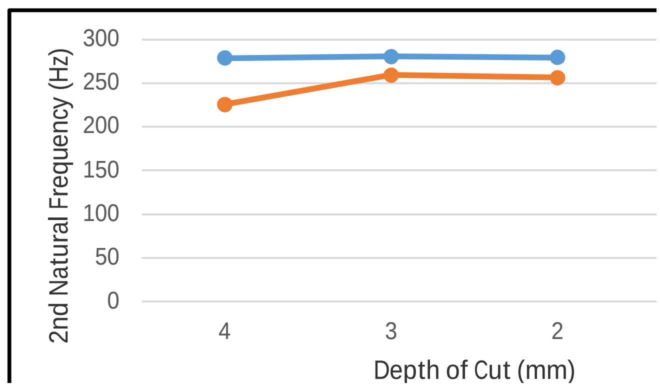

Fig.5.8 2nd Frequency vs DoC, crack at 150mm from fixed end

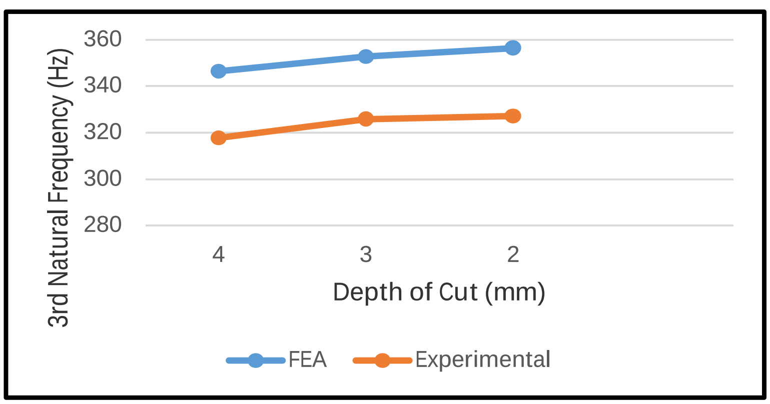

Fig.5.9 3rd Frequency vs DoC, crack at 150mm from fixed end

VI. CONCLUSION

A. For the same crack depth, the natural frequency increases as the position of the crack moves from fixed end to free end
B. The natural frequency of beam with crack is less than that of same beam without crack
C. Decrease in the natural frequency becomes more intensive with the growth of depth of crack
D. The increase of the beam length results a decrease in the natural frequency of the composite beam

VII. SCOPE FOR FUTURE WORK

The Vibration analysis of composite beam by introducing inclined cracks in place of transverse crack. Analysis on multiple cracks

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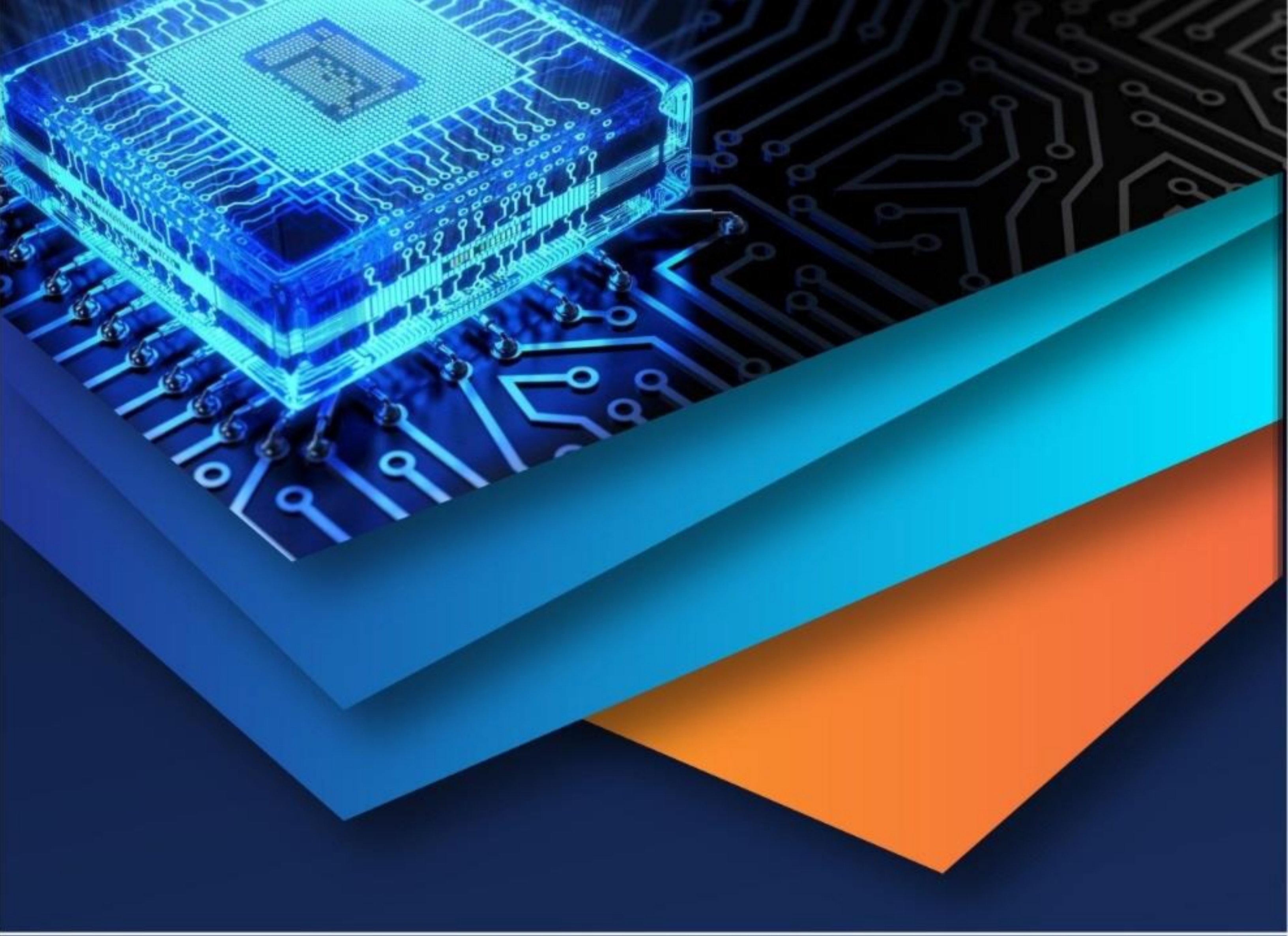

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