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Manufacturing and Experimental Testing of Carbon Fiber Composite Helicopter Blade

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Abstract: ***Now a days it is observed that weight parameter is a specific issue for many companies for better efficiency of any product. So, in recent a specific profile of light weight helicopter blade is designed. Due to composite material of carbon epoxy it is light in weight but also high strength carrying blade. The main scope of this project is to design a composite rotor blade using Carbon Fiber and Manufacturing it by using Hand layup process.***
In experimentation, Impact hammer test and FFT analyzer will be used for the validation purpose. Natural frequencies for helicopters blade structure with reinforcement will be calculated. Results and conclusion will be drawn by comparing analytical and experimental values. Suitable material will be suggested by analyzing the data along with future scope.
Keywords: Composite Material, Experimental Testing, Fabrication, FFT, Handlay UP, Natural Frequenvy

I. INTRODUCTION

A. Rotor Blade

The rotor blades of a helicopter are airfoils that provide aerodynamic forces when exposed to a relative motion of air across their surface. The rotational motion of the rotor hub initiated by the helicopter engine develops this relative motion, as well as forward, sideward and backward flight. While developing aerodynamics lift and drag forces, structural loads occur on the blades along their span and across their chord. A helicopter's rotor is generally made of two or more **rotor blades**. Each main rotor is mounted on a vertical mast over the top of the helicopter, as opposed to a helicopter tail rotor, which connects through a combination of drive shaft(s) and Gearboxes along the tail boom. [1]

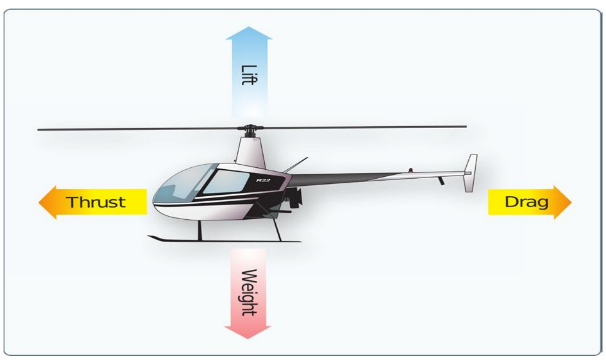

Fig 1.Helicopter Blade Forces Nomenclature

B. Material Selection

1) Properties of Carbon Fiber Composite

a) Carbon fiber composite are advanced composite material used in a wide range of applications from aerospace to automotive to sports equipment. When bound with plastic polymer resins, carbon fiber creates a composite material that is extremely strong, durable, and light weight
b) Carbon Fiber has High Strength to Weight Ratio (also known as specific strength)
c) Carbon fiber is Corrosion Resistant and Chemically Stable
d) Carbon fiber is electrically conductive and very rigid.
e) Resistance to Fatigue in Carbon Fiber Composites is good
f) Low Coefficient of Thermal Expansion
g) Good vibration damping, strength and toughness.

II. LITERATURE REVIEW

Dr. M Satyanarayana Gupta [1] Professor & HOD, Dept. of Aeronautical Engineering MLRIT, Hyderabad "Design and Analysis of Black Hawk UH-60 Rotor Blade Using Composite Materials", International journal and magazine of engineering, Technology, Management and Research. ISSN NO. 2348-4845.[1] In This Paper Black Hawk UH-60 has chosen for design, development and analysis. The blade configuration details including the plan form, taper, root joint and profiles was studied. The various load cases were analyzed.

Sara Arbo Torrentet [4] This study explores the geometry of sliver steel supports have on aero mechanics performance of a membrane aerofoil.

Experimental condition-Test are performed at low Reynolds number Re=9x10^4 and incidence of 2-25^0,high speed photogrammetric as well as force measurements are carried out to explore the effects of four different leading edge (LE) and trailing edge (TE) designs on the performance of membrane aerofoil.

Results indicate that mean camber as well as membrane vibration (both mode shape and frequency) change with geometry and size of LE and TE support. The LE/TE supports with a rectangular cross section consistently provide higher lift forces and higher mean camber deformation compared to the circular cross section.

M. Nazmul Haque [3] this paper represents the experimental investigation to explore better aerodynamic performance by incorporating curvature at the leading edge of a wing.

Experimental condition- A wooden model with straight leading and trailing edge i.e. rectangular platform and another model with curved leading edge and straight trailing edge are prepared with NACA 4412 airfoil in equal length (span) and surface area. Both the models are tested in a closed-circuit wind tunnel at air speed of 85.35 kph (0.07 Mach) i.e. at Reynolds's number 1.82 x 10^5. The static pressure at different angles of attack (-4˚, 0˚, 4˚, 8˚, 12˚, 16˚, 20˚ & 24˚) are measured from both upper and lower surfaces of the wing models through different pressure tapings by using a multi-tube water manometer. From the static pressure distribution, lift coefficient, drag coefficient and lift to drag ratio of both the models are analyzed.

Results-After analyzing the data, it is found that the curved leading edge wing platform is having higher lift coefficient and lower drag coefficient than the rectangular wing platform. Thus, the curved leading edge platform is having higher lift to drag ratio than the rectangular platform.

Nour, A., Gherbi, M.T., Chevalier, Y. (2012) [8]

This study concerns the dynamic behavior of a helicopter blade. The objective is to simulate by the finite elements method, the behavior of a blade of different materials under an aerodynamic load. This study was conducted to evaluate the aerodynamic loads applied and evaluated by a numerical simulation the frequencies and Eigen modes and calculate the stresses acting on the structure for different modes.

Experimental condition-The geometry of the blade is determined using CATIA software. Data is processed by the ANSYS software to mesh. The NACA 23012 wing airfoil is studied 5-digit serial. It is composed of 26 static pressure taken, numbered from 1 to 12 extrados side, and 13 to 24 from intrados side. The wing span for b = 6 m and chord c = 0.4 m

To describe the variation of the second degree of the centrifugal inertial force in the axial direction, it has an element of 8 nodes (I.J.K.L.M.N.O.P) has five degrees of freedom to each node: three translations in (Ux.Uy.Uz) following x, y, z, and two rotations (θx. θz) along x, z.

Result- We can conclude from these analytical and numerical modeling approaches that the dynamic behavior of the helicopter blade of different materials, as frequencies of isotropic material are higher compared to the orthotropic material. The stresses of an isotropic material is larger compared to the orthotropic material and becomes more rigid in the loading direction and is more ductile in other directions.

The results of numerical simulation for transient behavior, at the resonance, show clearly that the graphs representing the spectrum of various displacements are distributed over the entire range of time, which means that our blade works by the three modes (flapping, lagging, and twisting).

A. Problem Statement

In present research, light weight helicopter blade has been designed from carbon fiber composites. Due to aerodynamic structure of profile it generates a high lift on small angle of attack. FEA analysis along with FFT and Impact Hammer technique is used to study the parameters on blade design.

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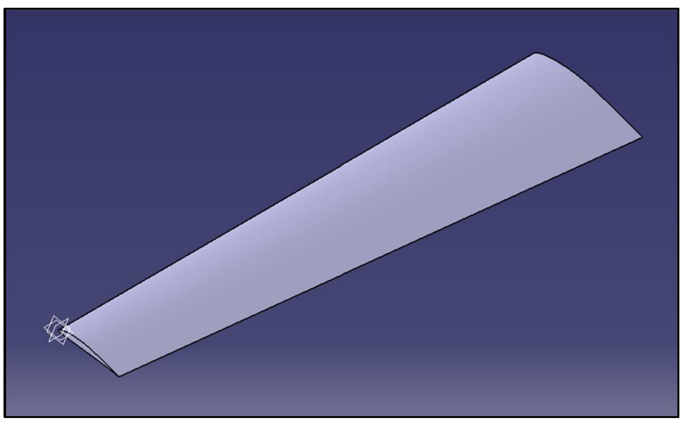
B. *Objectives*

1) Design of helicopter blade using standard process with from carbon fiber composite.
2) Modeling of blade using CATIA software.
3) Manufacturing of blade using composite material (Carbon epoxy) with hand layup process.
4) FEA analysis using ANSYS software to determine mode shape and respective frequency in modal analysis.
5) Experimental validation using FFT technique to determine natural frequency.

III. METHODOLOGY

1) *Step 1:-* Firstly identify problem regarding material of helicopter blade and go through literature survey with the help of various previous research papers.
2) *Step 2:-*Define objectives and problem statement by Survey on research papers which are relevant to this topic.
3) *Step 3:-* Selection of material for manufacturing of helicopter blade by surveying properties of different materials.
4) *Step 4:-* After that the components which are required for our project are decided.
5) *Step 5:-* Design and Development- After deciding the components, the 3D Model and drafting will be done with the help of CATIA software.
6) *Step 6:-* The modal Analysis of the components will be done with the help of ANSYS using FEA.
7) *Step 7:-* The Experimental Testing will be carried out with FFT analyzer and Impact Hammer testing.
8) *Step 8:-* Comparative analysis between the experimental & analysis result & then the result & conclusion will be drawn.

IV. DESIGN OF BLADE



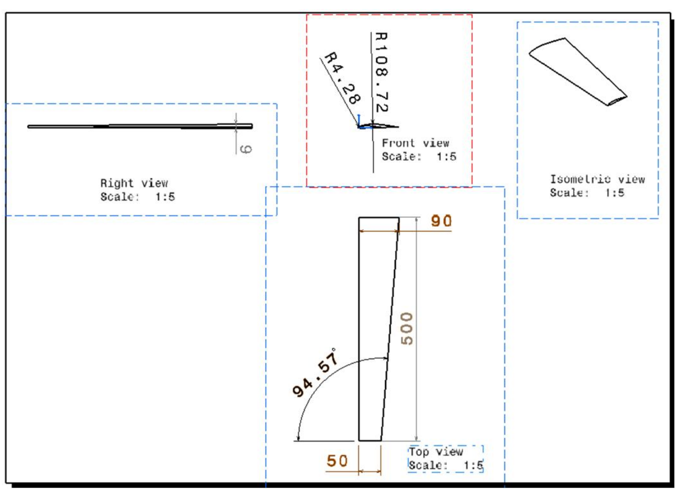


Fig. 2 Catia and drafting of blade design

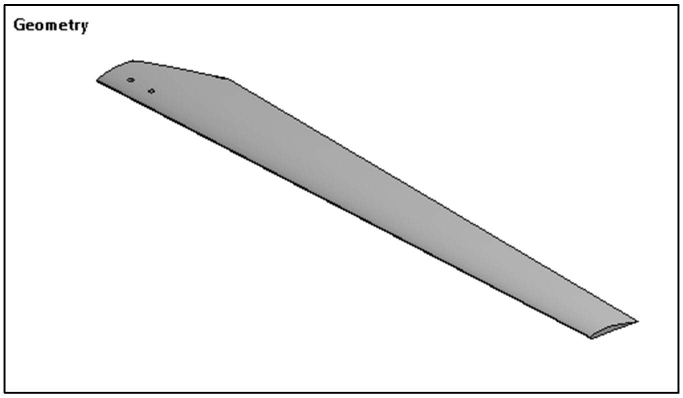


Fig. 3 Geometry imported in ANSYS

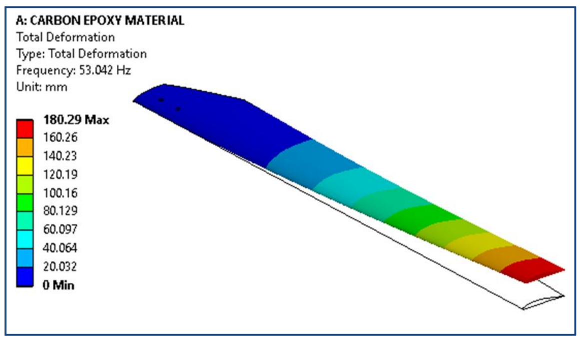


Fig.4 Mode shape 1

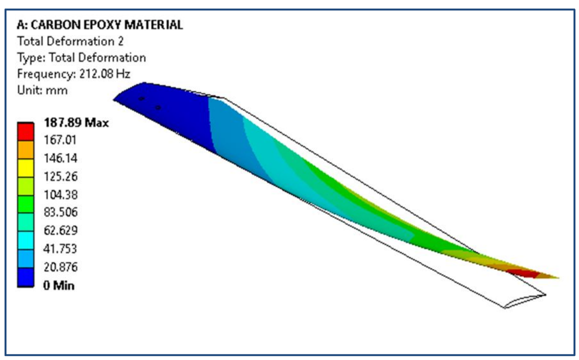


Fig.5 Mode shape 2

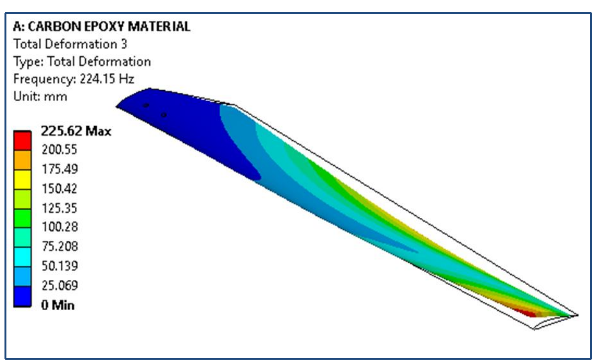


Fig.6 Mode shape 3

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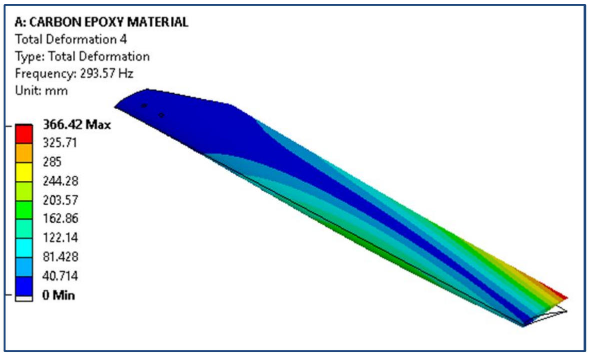

Fig.7 Mode shape 4

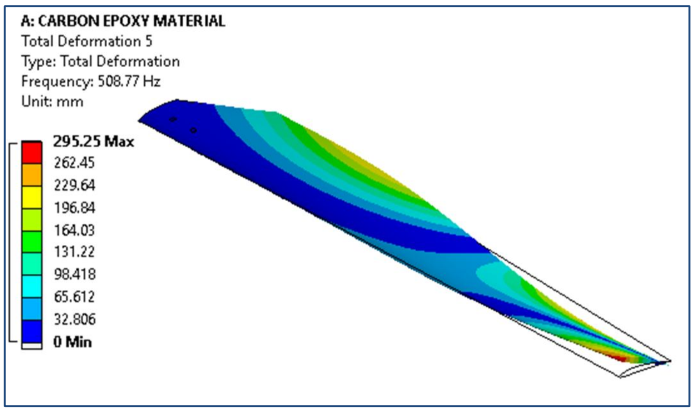

Fig.8 Mode shape 5

Tabular Data

	Mode	Frequency [Hz]
1	1.	53.042
2	2.	212.08
3	3.	224.15
4	4.	293.57
5	5.	508.77

Result- Mode shape of blade with respective natural frequency

V. MANUFACTURING PROCESS

A. Open Moulding

Composite materials (resin and fibers) are placed in an open mold, where they cure or harden while exposed to the air. Tooling cost for open molds is often inexpensive, making it possible to use this technique for prototype and short production runs.

B. Hand Lay-Up

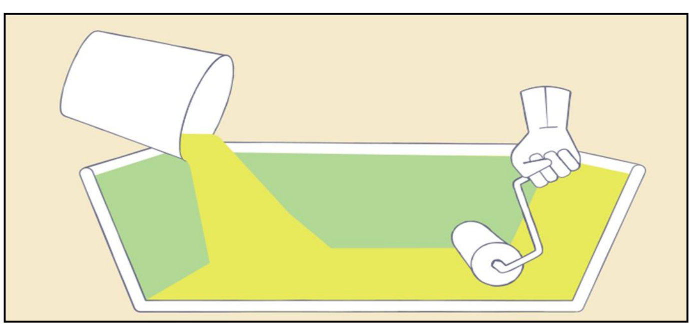

Fig.9 Hand layup process

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Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. Production volume per mold is low; however, it is feasible to produce substantial production quantities using multiple molds. Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment. With skilled operators, good production rates and consistent quality are obtainable.

C. Process

Gel coat is first applied to the mold using a spray gun for a high quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mold. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly wetting the reinforcement and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness. Low density core materials such as end-grain balsa, foam, and honeycomb, are commonly used to stiffen the laminate. This is known as sandwich construction.

VI. MANUFACTURING

A. Initially a fixture of C channel section is prepared with dimension of 90mm x 550 mm x 100 mm with thickness of 2 mm GI sheet.
B. Carbon fiber sheet is cut out with respective dimension of 90mm x 550 mm with 10 layers.
C. Solution is prepared with epoxy (50 ml) and hardener (1.5 bottle cap) is poured and gently stirred to form homogeneous solution.
D. Before mounting of first layer of carbon fiber, wax is applied at base of fixture so that after solidification of layer it can be easily removed.

Fig.10 Preparation of Fixture

Layer by layer reinforcement is provided with first layer lying up and gently applying epoxy solution with brush and repeating this process for 10 layers

Fig 11. Layer by layer Reinforcement

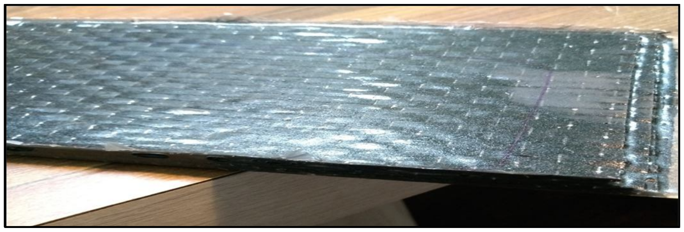


Fig 12. Shape Cutting for Blade

Desired shape is cut out from mould of blade to obtain required shape and size.

VII. EXPERIMENTAL TESTING

A. Fast Fourier Transform

This analysis can be expressed as a Fourier series. The fast Fourier transform is a mathematical method for transforming a function of time into a function of frequency. Sometimes it is described as transforming from the time domain to the frequency domain. It is very useful for analysis of time-dependent phenomena.

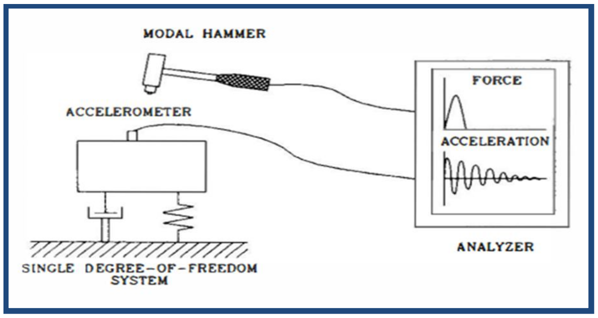
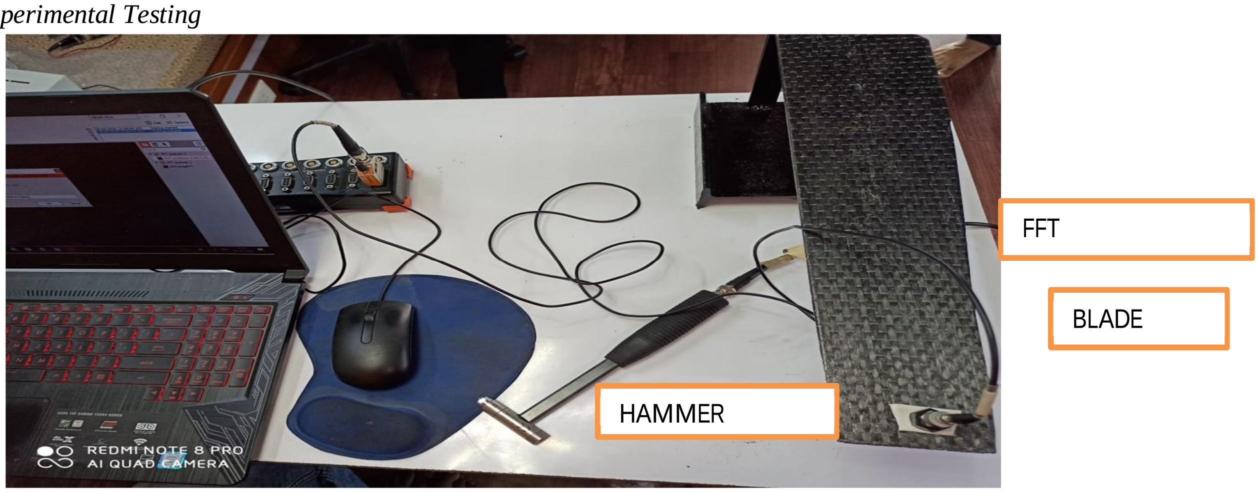


Fig 13. FFT construction

B. Impact Hammer Testing

Impact excitation is one of the most common methods used for experimental modal testing. Hammer impacts produce a broad banded excitation signal ideal for modal testing with a minimal amount of equipment and set up. Furthermore, it is versatile, mobile and produces reliable results. The use of impulse testing with FFT signal processing methods presents data acquisition conditions which must be considered to ensure that accurate spectral functions are estimated. Problems stem from the availability of only a finite duration sample of the input and output signals. When a structure is lightly damped the response to the hammer impact may be sufficiently long that it is impractical to capture the entire signal. . A phenomenon commonly encountered during impact testing is the so called "double hit". The "double hit" applies two impulses to the structure, one initially and one time delayed. Both the temporal and spectral characteristics of the "double hit" input and output are significantly different than a "single hit". The input force spectrum for the "double hit" no longer has the wide band constant type characteristics of a single hit. The purpose of this paper is to examine the use of impact vibration testing in relation to the constraints imposed by typical FFT' signal processing techniques. The characteristics of the impact testing procedure are examined with analytical time and spectral functions developed for an idealized test: a single degree of-freedom system excited by a half sine impact force. Once an understanding of the fundamental characteristics is developed it is applied to examine the specific situations encountered in structural impact testing. The relationship of the system's parameters with respect to data capture requirements is evaluated. The effects of exponential windowing are developed to examine the effects on the estimated spectra and modal parameters. Finally, the "double hit" phenomena is examined by combining the results from the single degree-of-freedom system excited by two impulses, one of which is time delayed. The results from these related studies are combined to provide insight into data acquisition guidelines for structural impact testing.

C. Experimental Testing



D. Result Of Experimental Testing

SR NO.	MODE	FREQUNCY (HZ)
1	1.	53.04
2	2.	212
3	3.	225
4	4.	293
5	5.	508

VIII. CONCLUSION

A. We can conclude from that Carbon fiber epoxy high natural frequency compared to other materials,
B. It can be analyzed after both analytical and experimental testing; Frequency result values are nearly matched.
C. Comparing the composite material and the conventional material, composite material has the low values of total deformation, stress and strain.
D. Hence it is concluded that composite material is suitable for the helicopter rotor blade.

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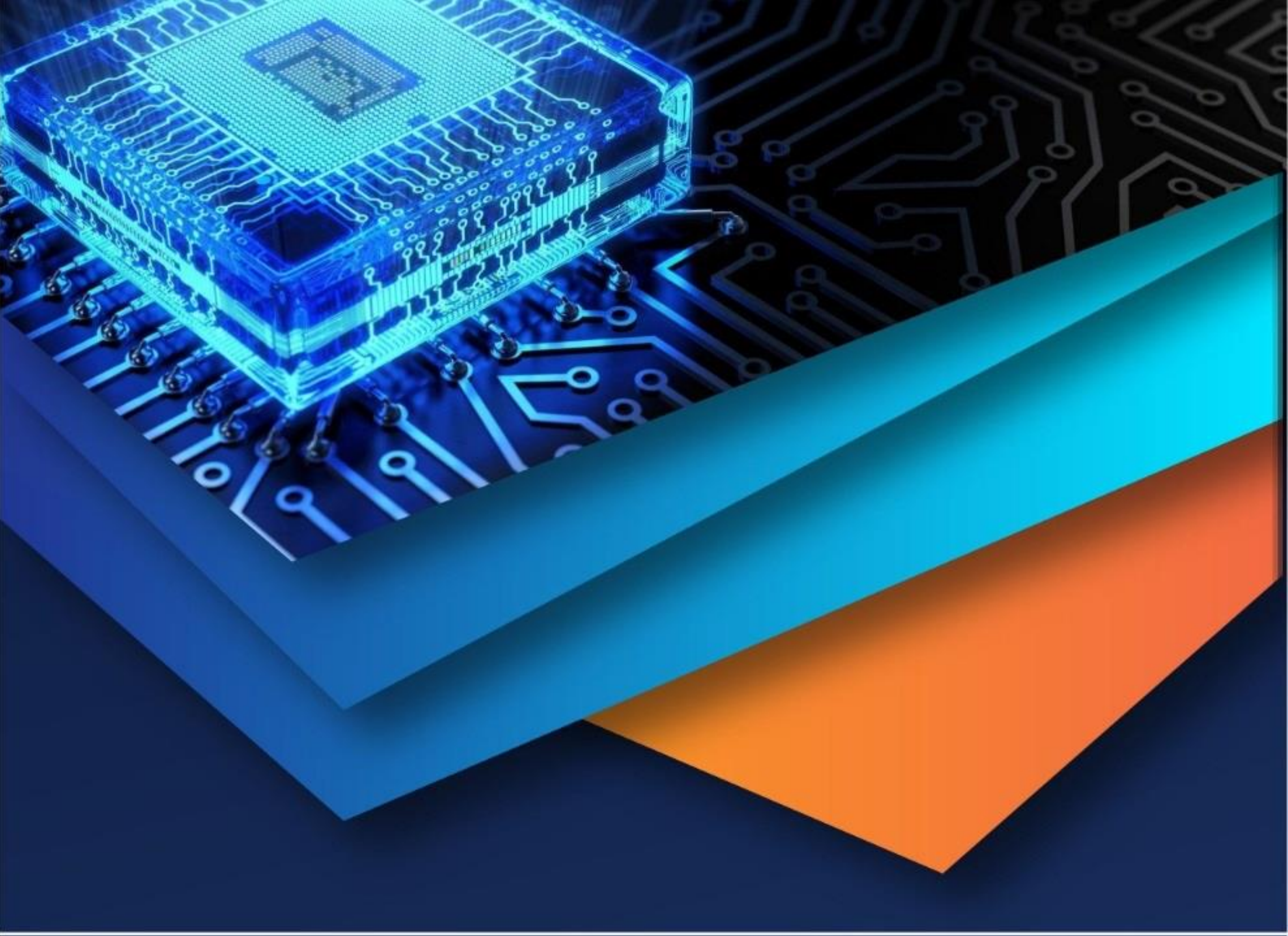

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