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# Static and Harmonic Analysis of a Fiber Reinforced Polymer Guyed Segment

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***Abstract:*** ***Fiber Reinforced Polymer is developed as a new advanced material in the market of infrastructural engineering. It is a good alternative to traditional steel for construction of infrastructures. In this paper a segment made up of FRP material have analysed in Static and Harmonic loading. The segment is assumed as a bottom segment of a 81m height tower and the height of segment is 8.6m supported with three guy lines for location Darbhanga. The analysis is done in ANSYS workbench software by using Finite Element Method. This research work involved the analysis of a 8600mm guyed segment of a telecommunication tower is subjected to static and harmonic loading and the results such as total deformation, equivalent stress and equivalent strains are estimated. On the basis of these results, simultaneously we can also estimate the results for full guyed tower with similar guyed arrangement and can also give the approximation of deformation for wind intensity more and less than Darbhanga. The segment has also analysed under harmonic loading by taking the value of frequency from 0 to 30 Hz to estimate the deformation, stress and strain frequency response. The value of optimum frequency can be estimated on the basis of results of harmonic analysis.***

***Keywords: FRP, ANSYS Workbench, Finite Element Analysis, Telecommunication guyed tower.***

## I. INTRODUCTION

Fiber reinforced polymer is a good replacement to economical steel due to its advantageous characteristics such as higher strength, lighter weight, good resistance to corrosion and fast installation time. Although FRP has some disadvantages like it is very poor to fire resistance, cost effective and it lose significant strength on bending. In this paper a tower segment of 8600mm height having equilateral triangular cross section as shown in figure 1 is analysed. The segment is supported by three guy lines without prestressing fixed to ground shown in figure 2 and the base of tower is pinned supported. The analysis is done on ANSYS workbench by using Finite Element Analysis [1]. In this research study a guyed segment of FRP material with 65% fiber volume fraction is analysed in static and harmonic loading.

The static and harmonic analysis is done for location Darbhanga a city of India that have higher wind intensity according to IS : 875 (part 3)-1987 [2]. The objective of study to explore the effects of material FRP with 65% fiber volume fraction on various output quantities like total deformation, equivalent stress and equivalent strain. The cross section given in figure 1 is taken from polyzois research [3], in his research he analysed a 81m tower of Fiber reinforced material in ANSYS apdl [1].

The assumption made for frequency range to determine the optimum frequency for deformation, stress and strain is taken (0 to 30 Hz).

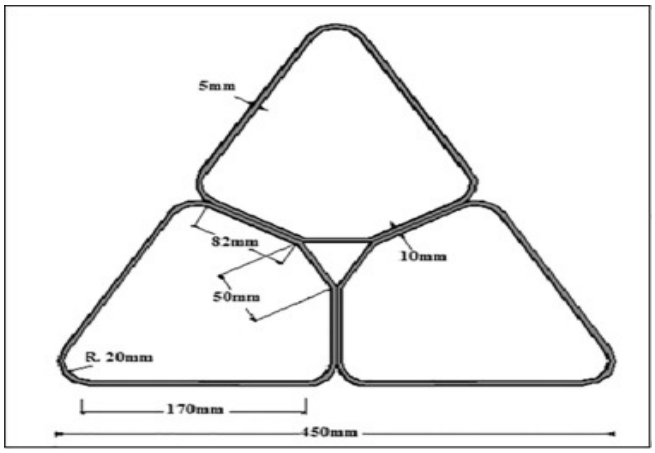


Figure 1: Equilateral Triangular cross-section of the segment.

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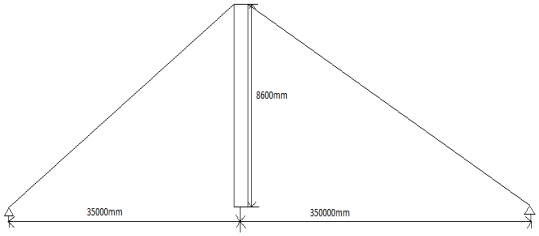


Figure 2: Elevation of the guyed segment

## II. MATERIAL PROPERTIES

The mechanical properties of FRP with 65% fiber volume fraction is determined after performing the burn-off test and coupon testing. D. Polyzois 2017 [3] has already given the properties in his research after performing these tests listed in table 1.

Table 1: Properties Of Frp Material With 65% Fiber Volume Fraction

| Parameters | Units | Mechanical Properties at $V_f$=65% | Coefficient of Variation (%) |
|---|---|---|---|
| $E_1$ | GPa | 47.71 | 1.4 |
| $E_2$ | GPa | 7.38 | 2.9 |
| $G_{12}$ | GPa | 4.15 | 14.8 |
| $\vartheta_{12}$ | | 0.30 | 5.79 |
| ρ | $(g/mm^{3)}$ | 0.0022 | – |

## III. WIND PRESSURE CALCULATION OF DARBHANGA LOCATION

According to IS-875 (Part-3) clause 6.3 [2] wind pressure for location Darbhanga is given below:
Location = Darbhanga
$V_Z = V_b k_1 k_2 k_3$
$P_Z = 0.6 V_Z^2$
Where,
$V_b$ = wind speed (55 m/s) for Darbhanga
$V_Z$ = design wind speed at any height z in m/s
$k_1$ = Probability factor (risk coefficient)
$k_2$ = Terrain, height and structure size factor
$k_3$ = Topography factor
$P_Z$ = design wind pressure in $N/m^2$ at height z
Here, z = 8.6m then calculated $P_Z$ = 1753.10 $N/m^2$

## IV. MODELLING AND LOADING

Finite element software ANSYS Workbench is used for getting precise results of the analysis, the. The highlights and details for modelling and load application are explained here.

### *A. Static Analysis*

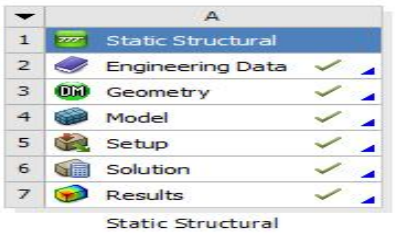


Figure 3: Schematic chart for static analysis.

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*1) Procedure for Static Analysis*

The procedure for analysis of 8.6m segment under static loading on ANSYS Workbench [1] is given below:

*a) Step-1:* Geometry
*b) Step-2:* Connections and joints
*c) Step-3:* Meshing of segment
*d) Step-4:* Boundary conditions and load application.
*e) Step-5:* Solutions and results.

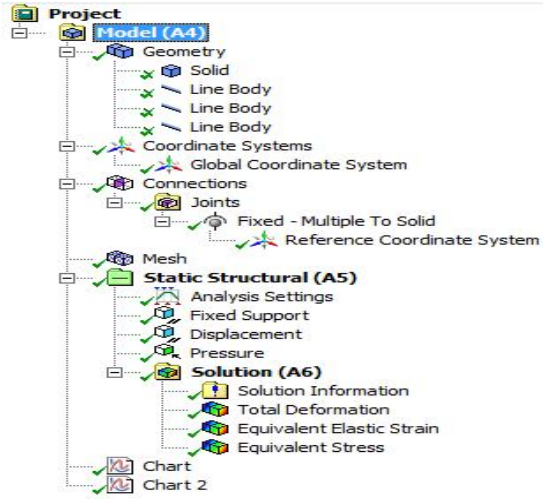


Figure 4 : Schematic chart representing the procedure for analysis.

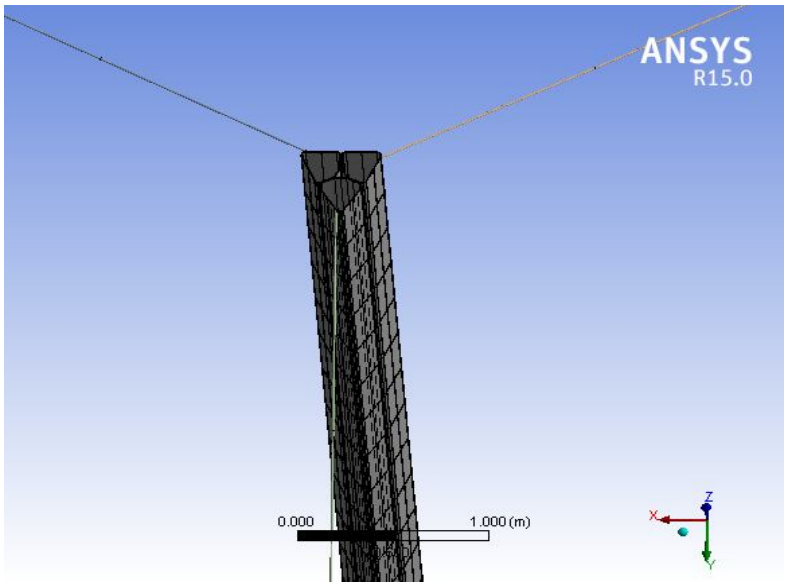


Figure 5 : Meshing of guyed segment

*2) Static Loading*

According to IS-875(part-3) clause 6.3 [2] we have already calculated above the designed wind pressure for Darbhanga city of India is 1753.10 N/m$^2$. To check the sustainability of FRP guyed tower segment with fiber volume fraction 65%, the analysis is done for one of the highest wind speed location (Darbhanga) in India.

*a)* Both ends of guy lines are fixed to the ground surface and vertices of the segment.
*b)* The base of the tower is supported as ( X=0, Y=0, Z=free).
*c)* The Wind Pressure acting normal to the face of the tower is 1573.10 N/m$^2$.

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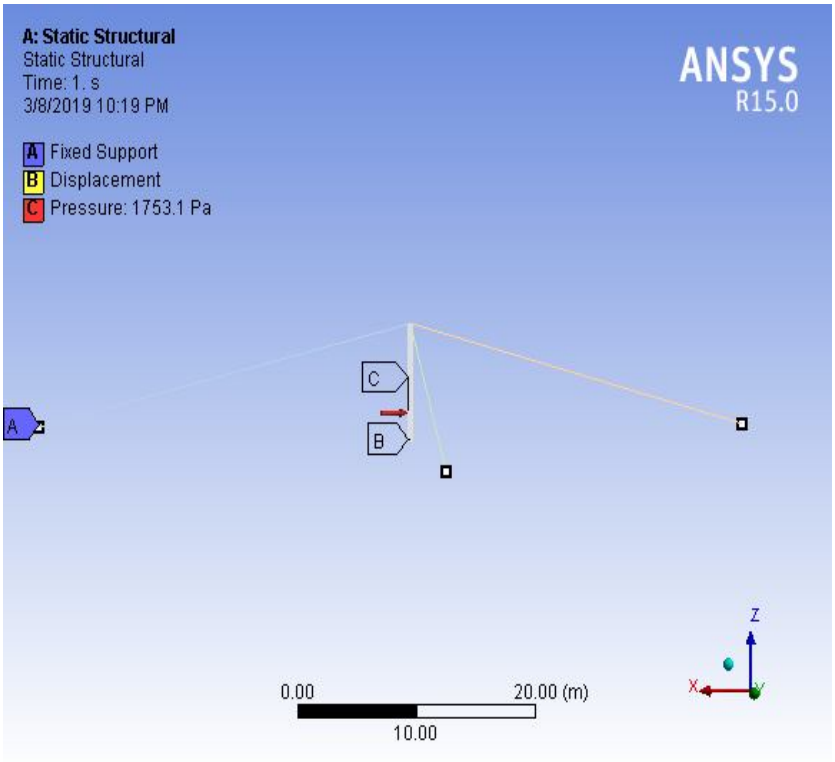


Figure 6: Representation of loading and boundary conditions.

*B. Harmonic Analysis*

In this analysis we input the frequency range (0 to 30Hz) (1) to estimate the frequency response and value of optimum frequency for total deformation, equivalent stress and equivalent strain under harmonic loading.

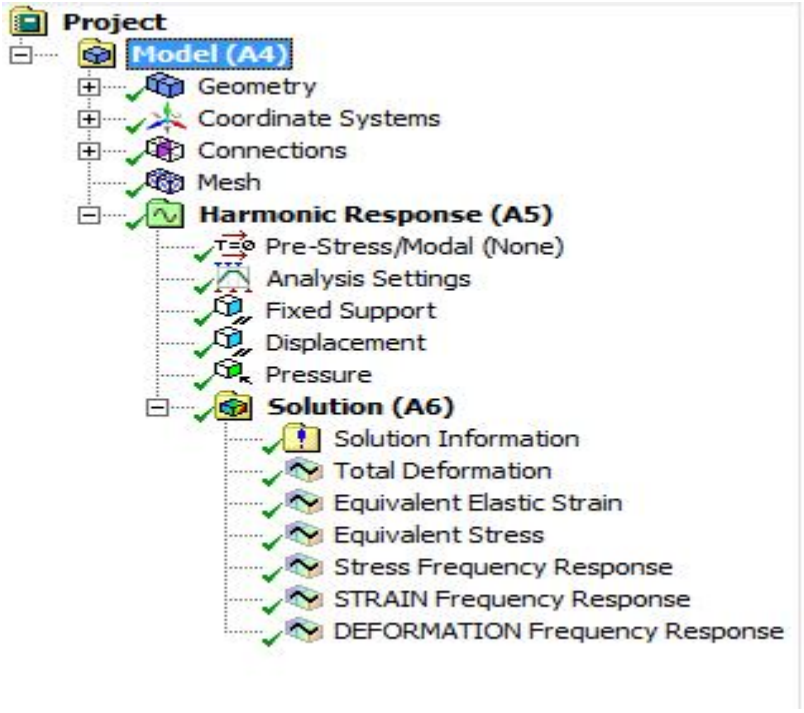


Figure 7: Procedure for Harmonic analysis

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## V. RESULTS AND COMPARISON

The results are available for static and harmonic response analysis for a guyed segment of FRP with 65% fiber volume fraction.

### *A. Results Obtained After Static Analysis*

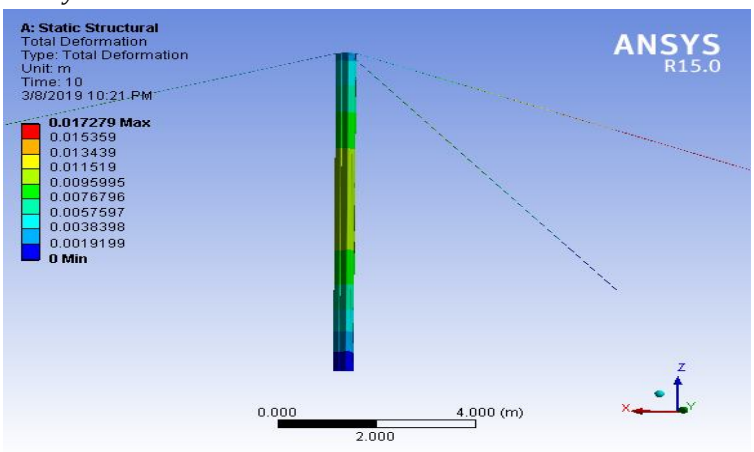


Figure 8 : Total deformation in 65% Vf guyed segment.

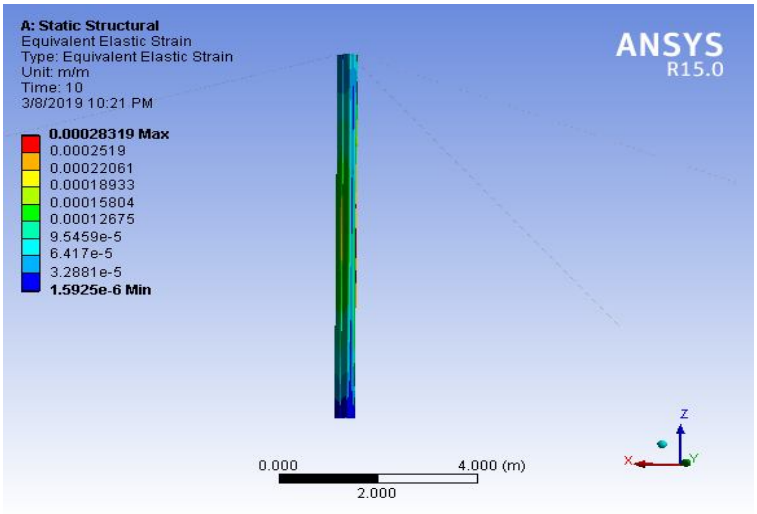


Figure 9 : Equivalent elastic strain in 65% Vf guyed segment.

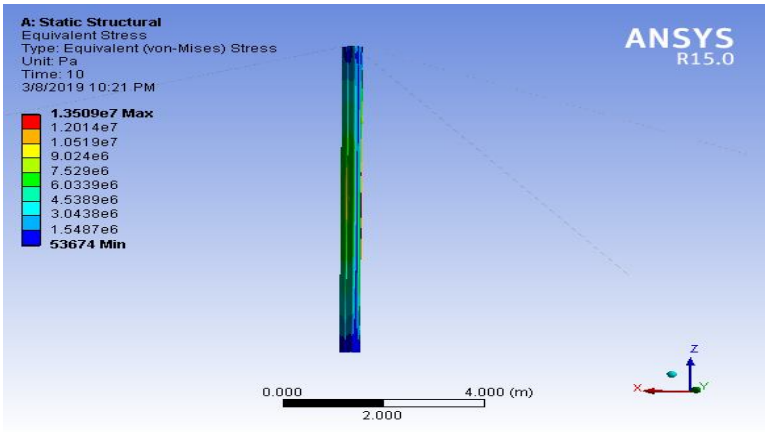


Figure 10: Equivalent stress in 65% Vf guyed segment.

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Table 2: The results for static analysis

| | | In guys | In mast |
|---|---|---|---|
| Total deformation(m) | Min | 0 | – |
| | Max | 1.7279e-2 | – |
| Equivalent elastic strain(m/m) | Min | – | 1.5925e-6 |
| | Max | – | 2.8319e-4 |
| Equivalent (von-mesis) stress(Pa) | Min | – | 53674 |
| | Max | – | 1.3509e+7 |

*C. Results Obtained after Harmonic Response Analysis are as Follows*

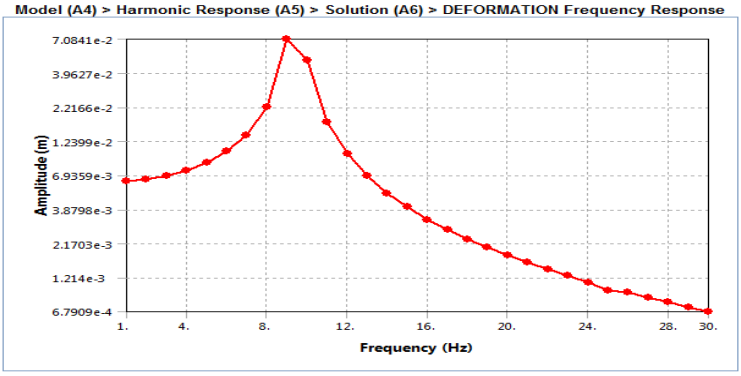


Figure 11: Deformation Frequency Response

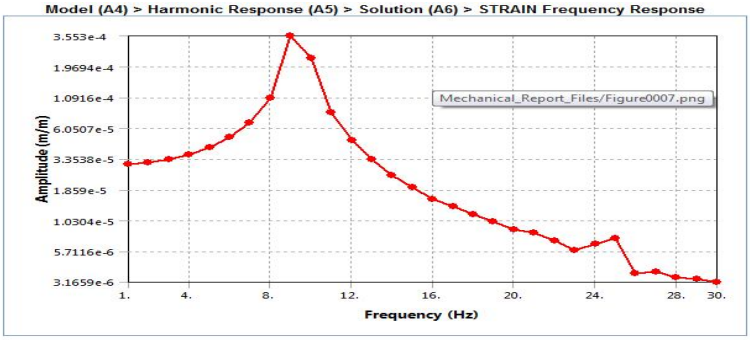


Figure 12: Strain frequency response

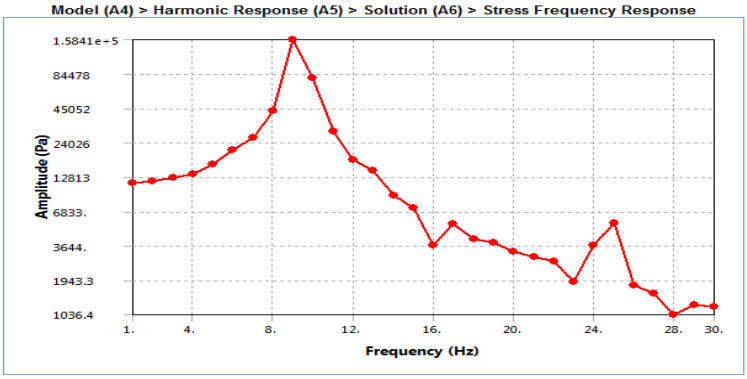


Figure 13: Stress frequency response

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Table 3: Results For Harmonic Analysis Are As Follows

| | Frequency (Hz) | Max. Amplitude |
|---|---|---|
| Deformation frequency response(m) | 9 | 7.0841e-2 |
| Strain frequency response(m/m) | 9 | 3.553e-4 |
| Stress frequency response(Pa) | 9 | 1.5841e5 |

## VI. CONCLUSION

This analysis study of guyed segment concludes that the total deformation developed in guy lines only and equivalent stresses and strain will develop in mast for wind intensity of Darbhanga location according to IS 875 part 3 (clause 6.3) [2].

On the basis results of Harmonic analysis the value of optimum frequency is 9Hz for deformation, stress and strain frequency responses. In this study we analysed a8600mm segment and found out the mechanical behaviour of the segment in static and harmonic condition and on the basis of static results we can simultaneously estimate the mechanical behaviour of full tower upto any height for Darbhanga region.

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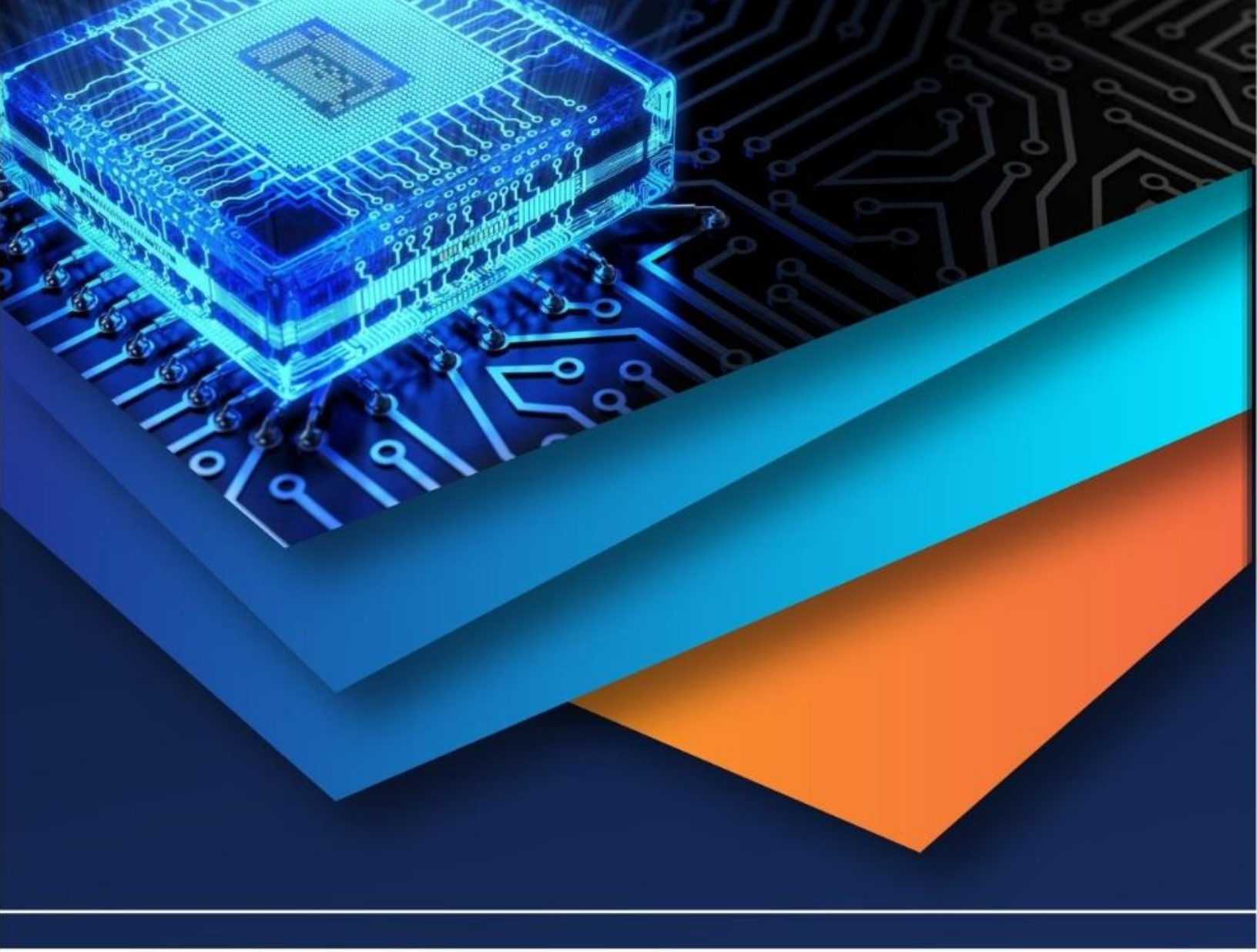

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