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Design and Strength Optimization of Steering Yoke with Composite Reinforcement

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***Abstract:** In the present era of 21st century, and the increasing industrial innovations i.e. Industry 4.0 has led to many revolutions in the field of designing and manufacturing too keeping environment and sustainability in vision. Composite materials have led to a new perspective towards traditional machining and designing. Steering Yoke not only helps in the turning of an automobile but also damping of the shocks from the suspension and comfort of driving. This project focuses on the analysis, topological optimization, composite reinforcement of the steering yoke without hampering the required strength for its functional ability. Further static and dynamic validation of the model will be carried out using FFT analyzer by finding out the modes and natural frequency of the yoke. The analysis will be carried out on ANSYS (ACP) and the 3D model on CATIA software*.

***Keywords:** Composite Material, Topology Optimization, FFT Analyzer, ANSYS, Carbon Fibre*

I. INTRODUCTION

A steering yoke primarily converts rotary motion from the steering wheel to transverse motion in the rack and pinion system to turn a vehicle. Rack and pinion are a integral part of the steering assembly. The vibrations from the suspension assembly are transferred to the steering assembly which induces ununiform stresses results in disengaging of the rack from the pinion further leading to loss in control and accidents.

II. LITERATURE REVIEW

Clarence Spicer in 1904 innovated Cardon Joint which is also known as Universal joint, steering yoke is a type of universal joint which is used in the steering assembly of an automobile [1].

The major reason for the failure of universal joint is fracture and fatigue stress. The high stress regions resulted in the crack initiation and fatigue cycles led to propagation of these cracks leading to failure was stated by Bayrakceken. He also analysed the failure of pinion shaft [2].

Failure in transmission system result in one-forth of failures in automobiles. Heyes found out the root cause for these failures as restriction in manufacturing, designing and negligence in maintenance [3].

A optimal design in compliance with tolerances and manufacturing restrictions was proposed by Hummel and Chassapis. They also proposed the optimal chronology for design of a ideal cardon joint [4].

To implement the cardon joint in various applications Dodge and Everden formulated a theory to design the joint using minimum diameter and torque applied on it. They also studied that the failures in the joint occurred due to uneven cyclic loading [5][6].

Cooney and Wagner stated a optimum theory by analysing the kinematics and strength of a ideal joint which was based on assuming small angles between the joints and neglecting the interference between them [7].

Surface texturing helps to achieve desirable properties of composite materials as per the application. Sasaki stated the effect of surface texturing of the bearing in the cardon joint [8].

III.PROBLEM STATEMENT

The present problem prevailing in the electric vehicles is the mileage and the sustainability of the natural resources required in the process. Also mining these natural resources lead to pollution causing increase in carbon footprint.

The efficiency of the electric vehicles can be increased by reducing the weight of the components of the vehicle in compliance with the safety and functional ability. The present scenario requires modern ways of manufacturing, designing and optimizing existing designs.

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IV. DESIGN OF STEERING YOKE

A steering yoke of Maruti Suzuki Ertiga is selected to perform analysis and experimentation, so CATIA is used as a 3D modelling software to create model

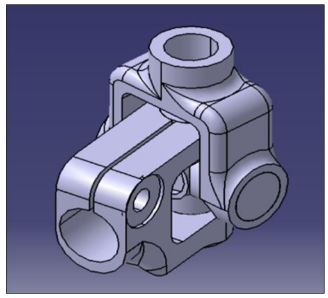

Fig.1 CAD model of Steering Yoke

V. FINITE ELEMENT ANALYSIS

The prepared CAD model is now imported into ANSYS ACP software for analysing in which the boundary conditions are applied wherein one end of the yoke is fixed and torque is applied over the other end.

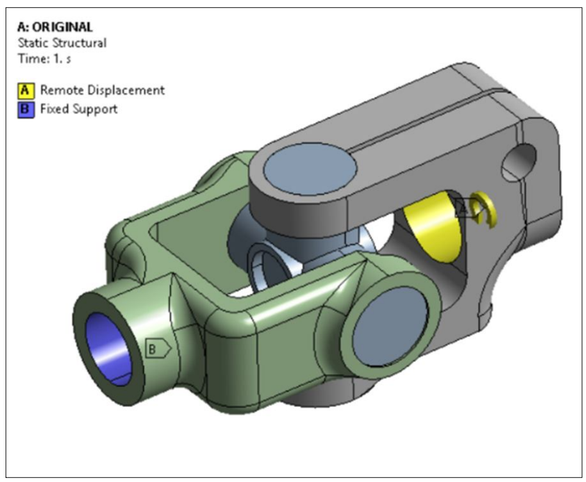

Fig. 2 Boundary Conditions

The results obtained are based on 0.1 degree of rotation of the yoke.

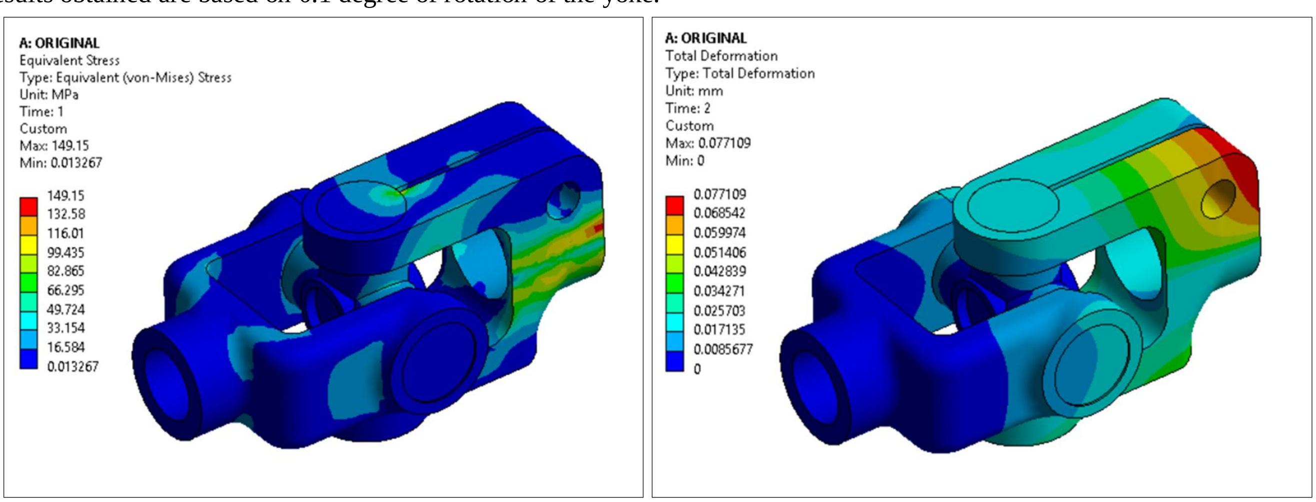

Fig. 3 Equivalent Stress and Deformation

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In order to obtain the maximum torque transmitted the reaction torque is analysed on the fixed end of the steering yoke.

Maximum Value Over Time	
X Axis	4452.7 N·mm
Y Axis	-407.86 N·mm
Z Axis	-17690 N·mm
Total	35668 N·mm

Fig. 4 Reaction torque

VI. TOPOLOGY OPTIMIZATION

Topology optimization is a mathematical approach that optimizes material layout within a given design space, for a given set of loads and boundary conditions such that the resulting layout meets a prescribed set of performance targets.

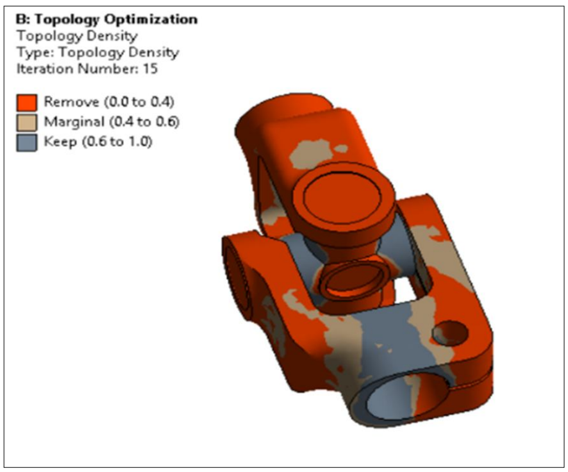

Fig. 4 Toplogy Optimisation

The orange region indicates the mateial removal zone. For our study 3 mm material is removed from the top and bottom layer.

VII. COMPOSITE MATERIAL

Composite materials are now being used on a large scale due to their enhanced properties induced due to the mixture of two or more materials with different physical and chemical properties. The enhanced properties are based on applications which may require strength, light weight, stiffness, resisitant to electricity ot corrossion.

Condition	Types of fibers used in composite		
	Carbon Fibers	Glass Fibers	Aramid Fibers
Tensile Strength	Very Good	Very Good	Very Good
Young's Modulus	Very Good	Good	Adequate
Long-term behavior	Very Good	Good	Adequate
Fatigue behavior	Excellent	Good	Adequate
Bulk density	Good	Excellent	Adequate
Alkaline resistance	Very Good	Good	Inadequate
Price	Adequate	Adequate	Very Good

Table 1. Compairion Composite Material

On studying the various mechanical properties of the various composites and then comparing them with one another, it is found that Carbon Fibre is the best suitable material as per our requirement for the project.

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VIII. ANALYSIS ON OPTIMISED YOKE WITH CARBON FIBER

The same boundary conditions as that applied on existing yoke will be applied.

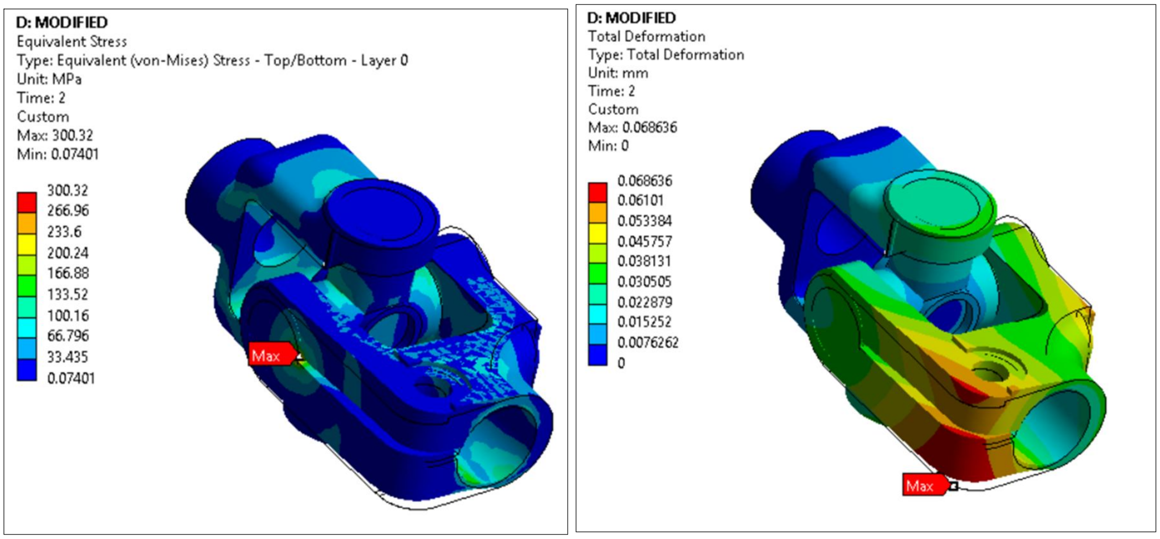

Fig. 5 Equivalent Stress and Deformation

Maximum Value Over Time	
X Axis	3330.1 N·mm
Y Axis	-277.74 N·mm
Z Axis	-27513 N·mm
Total	55130 N·mm

Fig. 6 Reaction torque

IX. MODAL ANAYLSIS

Modal Analysis is carried out for finding out the natural frequency and modes of the yoke

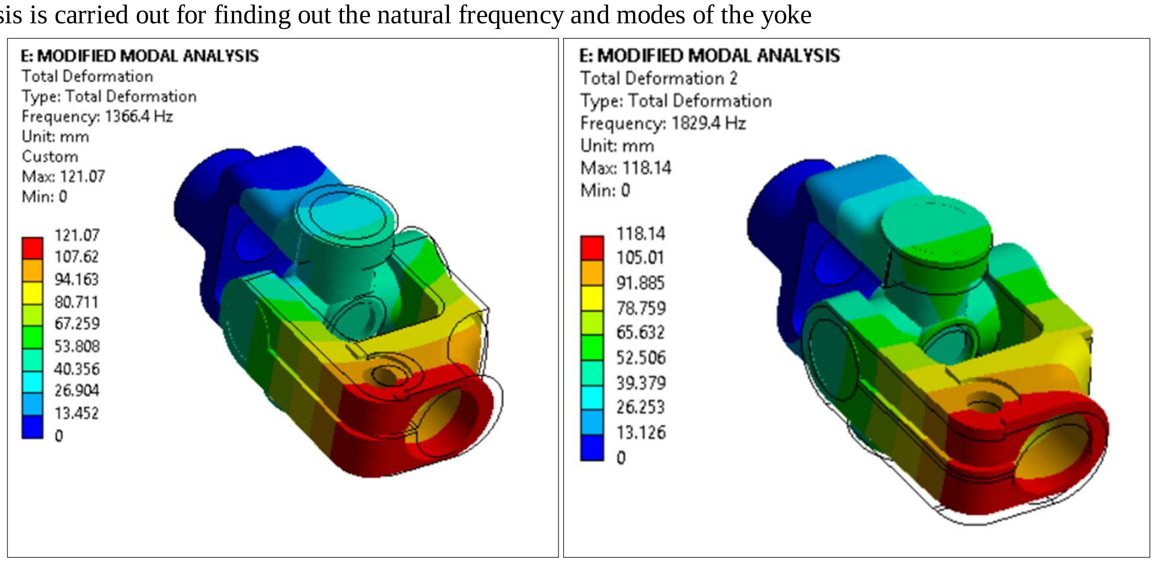

Fig.7 Mode 1 and Mode 2

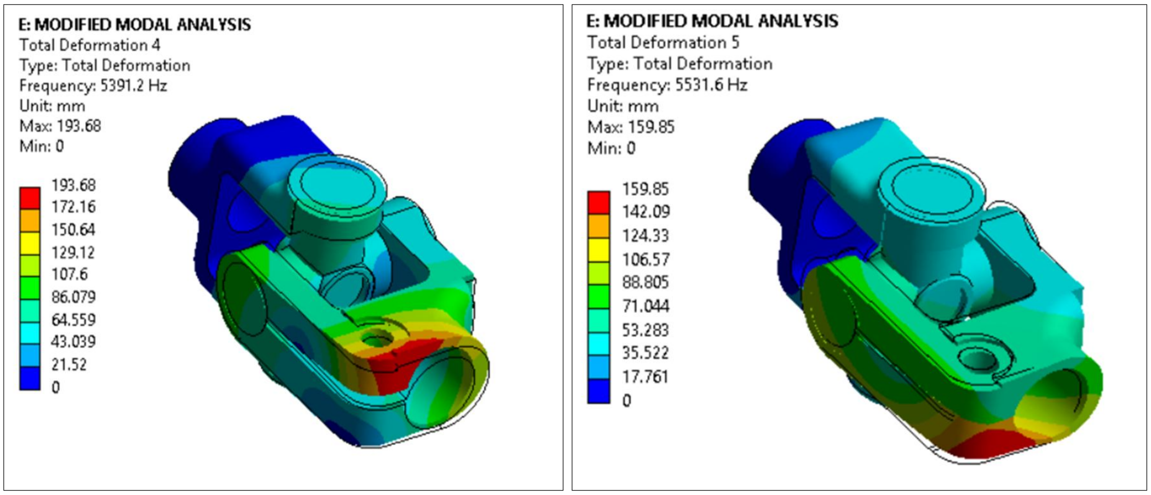

Fig. 8 Mode 3 and Mode 4

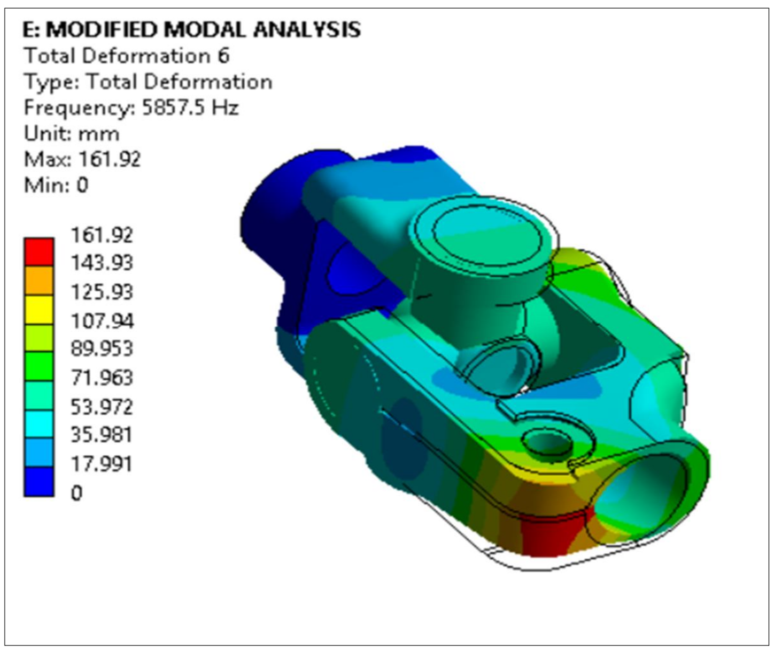

Fig. 9 Mode 5

X. EXPERIMENTAL PROCEDURE

The experimental validation is done by using FFT (Fast Fourier Transform) analyser. Fourier analysis of a periodic function refers to the extraction of the series of sines and cosines which when superimposed will reproduce the function. This analysis can be expressed as a Fourier series. Sometimes it is described as transforming from the time domain to the frequency domain. It is very useful for analysis of time-dependent phenomena.

A. Steps

1) Initially fixture is designed according to existing boundary condition as per FEA results.
2) FFT consists of impact hammer, accelerometer, data acquisition system in which each supply is applied to DAS and laptop with DEWSOFT software to view FFT plot.
3) Accelerometer is mounted at edge as per high deformation observed in FEA results along with initial impact of hammer are placed for certain excitation to determine frequency of respective mode shapes.
4) After impact FFT plot are observed on laptop and comparison of FEA and experimental results are analysed.

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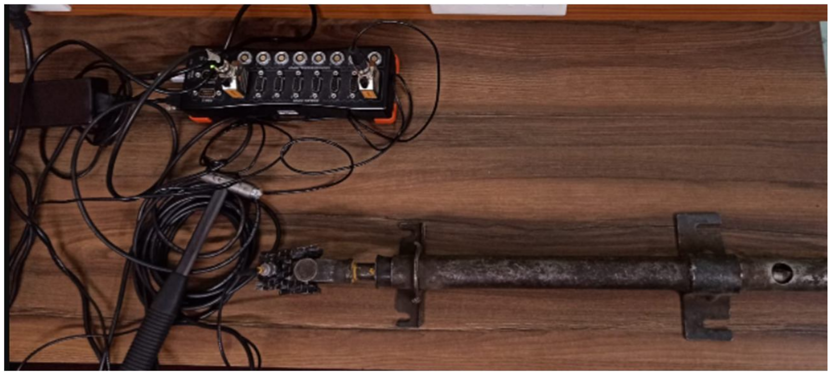

Fig. 10 Experimental Setup

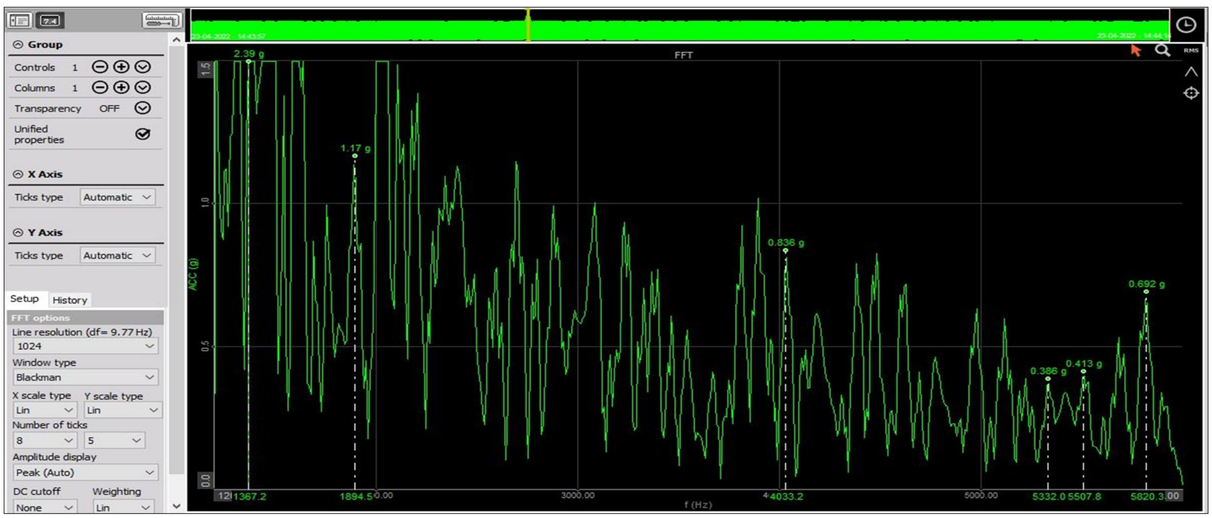

Fig. 11 Results obtained from FFT Analyzer

Mode shape	FEA (Hz)	Experimental (Hz)
1	1366.4	1367.2
2	1829.4	1894.5
3	3951.3	4033.2
4	5391.2	5332.0
5	5531.6	5507.8
6	5857.5	5820.3

Table. 2 Comparing Results

XI. CONCLUSION

1) In this project, design and optimisation of the steering yoke is done for weight and strength optimisation.
2) The 3D modelling of the steering yoke is done using CATIA Software.
3) The stress analysis of the yoke is completed by using static structural analysis with the help of ANSYS software.
4) The static structural analysis performed to find out equivalent stress and total deformation on the original yoke after applying moment on the geometry. The total deformation observed on the steering yoke is 0.07 mm and Equivalent stress is 149 MPa. FEA for Existing steering yoke is done and stress plot and deformation plot is observed.
5) Analysis on optimized reinforced steering yoke is done using Ansys software.
6) Load bearing capacity for reinforced steering yoke is observed to be better than existing steering yoke.
7) Natural frequency of reinforced steering yoke validates using FEA and FFT analyser and impact hammer test.

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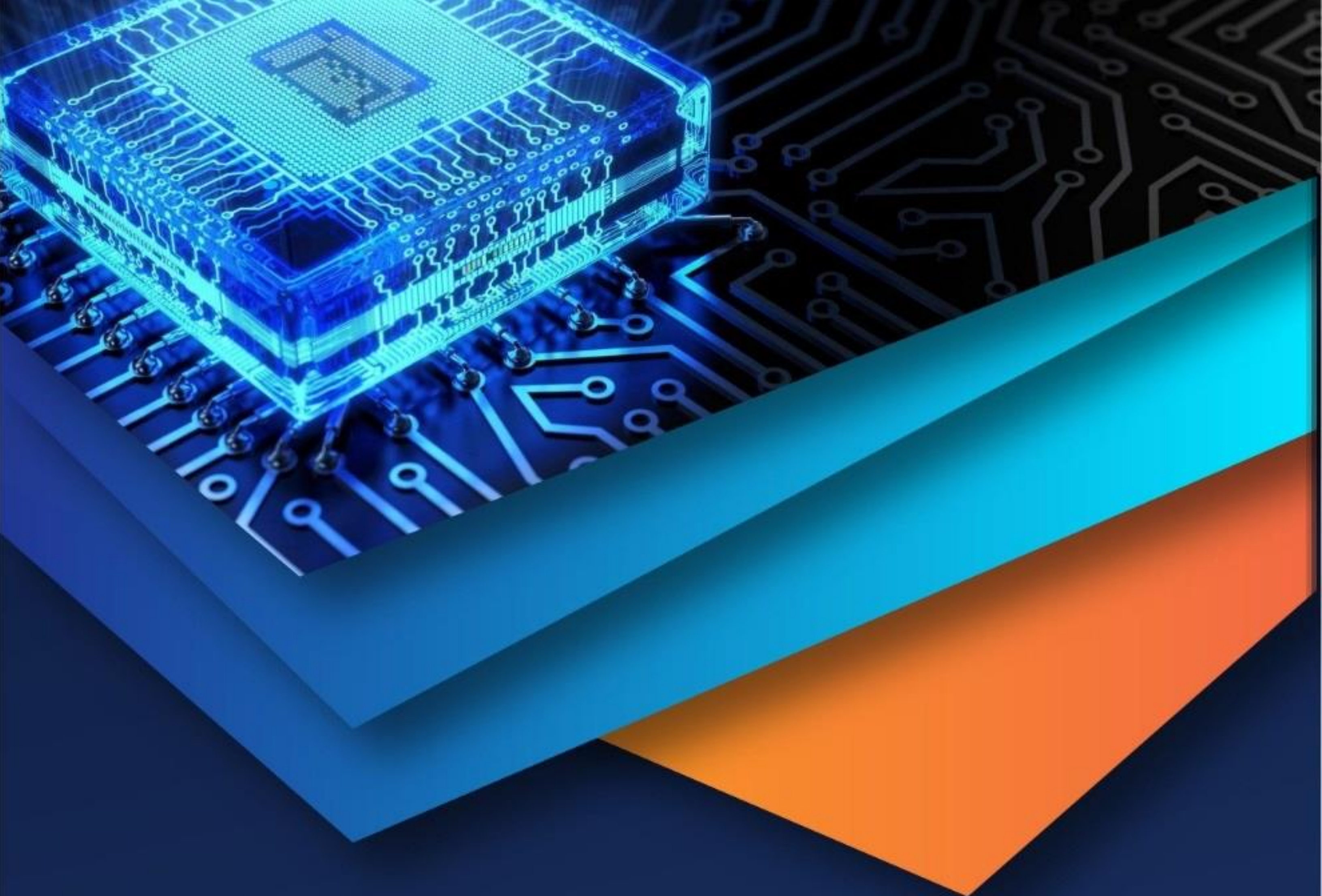

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