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Development of Automobile Aluminum/CFRP Hybrid Steering Knuckle

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Abstract: The suspension system of a vehicle plays an important part in precisely controlling the stir of the wheel throughout the trip. The perpendicular and the side dynamics (lift and running) are affected by the unsprung to sprung mass rate. Lower value of this mass rate leads to enhanced performance of the auto. Light weight and low fuel consumption are the two main demands for a vehicle. To optimize the unsprung mass of the auto, the design of the control arm plate is optimized with Aluminum material, and Carbon fiber corroborated compound control arm frames are used to achieve high stiffness to weight rate. This leads to an increase in the overall power-to-freight rate of the auto which helps to deliver maximum performance to the Vehicle. The improved design obtained had achieved 45.8% reduction of mass while meeting the strength requirement

I. INTRODUCTION

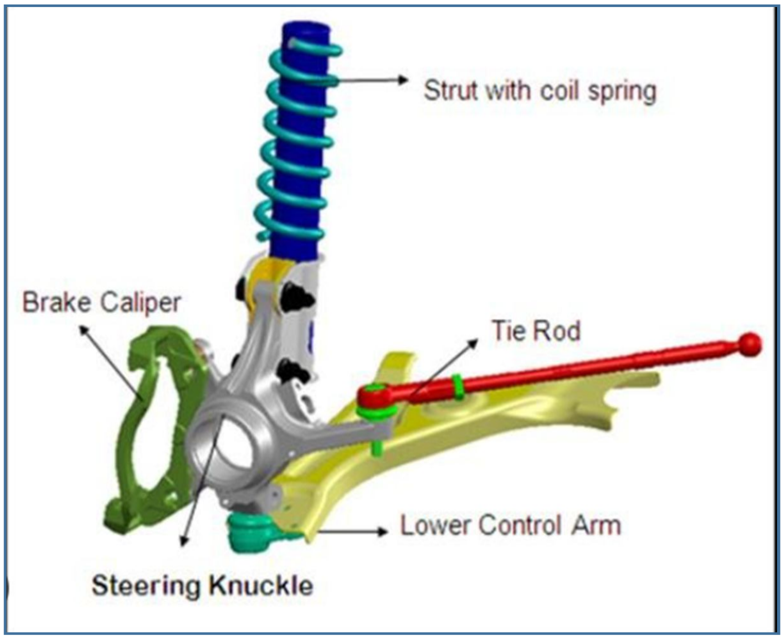
The suspense of ultramodern vehicles needs to satisfy several conditions such as lading, driving conditions, and type of road face. The steering knuckle is one of the main factors used in the McPherson suspense system shown in Figure subordinated to millions of varying stress cycles during its service. There's a considerable exploration of the design and optimization of a knuckle grounded on fatigue life and weight reduction. A major issue in vehicle assiduity is the presence of variability in the physical parcels and manufacturing processes. Deterministic approaches are unfit to take into account this variability without leading to large structures. The necessity of assessing the robustness of a particular design requires a methodology grounded on continuity and design optimization through probabilistic models of design variables (DOE). In general, it's linked to the steering knuckle which is one of the critical factors of the vehicle that links suspense, steering system, wheel mecca, and boscage to the lattice. We've linked the below problem the process of optimizing the design using a methodology grounded on continuity and design optimization. Knuckle, knuckle and passenger buses knuckle six orders; press accouterments and manufacturing styles used forged knuckle into cast Aluminum and cast iron steering knuckles three sections; their characteristic shape into pole class knuckle, knuckle class center hole and covering class Pole class knuckle substantially composed of the stem portion, flanges and branches rights, and more generally for large, Mid-sized buses and motorcars in; center hole order substantially consists of the base knuckle, flange, and right branches, the base center hole, a Generally used for driving the auto in which the frontal axle; containing class Knuckle substantially by pole, sleeve and flange Composition.

A. Knuckle

Knuckle, knuckle and passenger cars knuckle six categories; press materials and manufacturing methods used forged knuckle into cast Aluminum and cast iron steering knuckles three sections; their characteristic shape into pole class knuckle, knuckle class center hole and casing class Pole class knuckle mainly composed of the stem portion, flanges and branches rights, and more generally for large Mid-sized cars and buses in; center hole category mainly consists of the base knuckle, flange and right branches, the base center hole, a Generally used for driving the car in which the front axle; casing class knuckle mainly by pole, sleeve and flange composition.

The parts of the steering knuckle component are given below:

1) Suspension Mounting Upper Arm/Strut Mount
2) Tie Rod Mounting / Steering Arm
3) Lower Ball Joint /Suspension Mounting Lower Arm
4) Ball Bearing Location / Stub Hole 5. Brake Caliper Mounting.



B. Problem Statement

A Steering Knuckle is one of the critical factors of the vehicle which connects boscage, suspense, wheel mecca, and steering system to the lattice. It undergoes varying loads subordinated to different circumstances, while not distressing vehicle steering performance and other asked vehicle characteristics. The global automotive assiduity is driving more strict quality targets to meet adding and strict emigrations regulations and client demand for extended range electric vehicles. The weight reduction of this particular non-spring element increases the relative effectiveness of the spring and shock absorber, thereby perfecting passenger comfort and motorist running. This recently developed compound steering knuckle part proves to be suitable for the high performance of petrol machines or electric vehicles. The aluminum/ CFRP mongrel part also doesn't increase part volume, meeting tight package space restrictions and allowing a single-part design to be used across multiple models in a vehicle.

II. OBJECTIVES

1) 3D modeling of existing steering Knuckle and perform static structural analysis by using ANSYS workbench.
2) To perform static and modal analysis of aluminum/CFRP hybrid steering Knuckle.
3) testing of aluminum/CFRP hybrid steering Knuckle on Universal Testing Machine.
4) Comparative analysis between FEA and Experimental model. Conclusions and Future scope.

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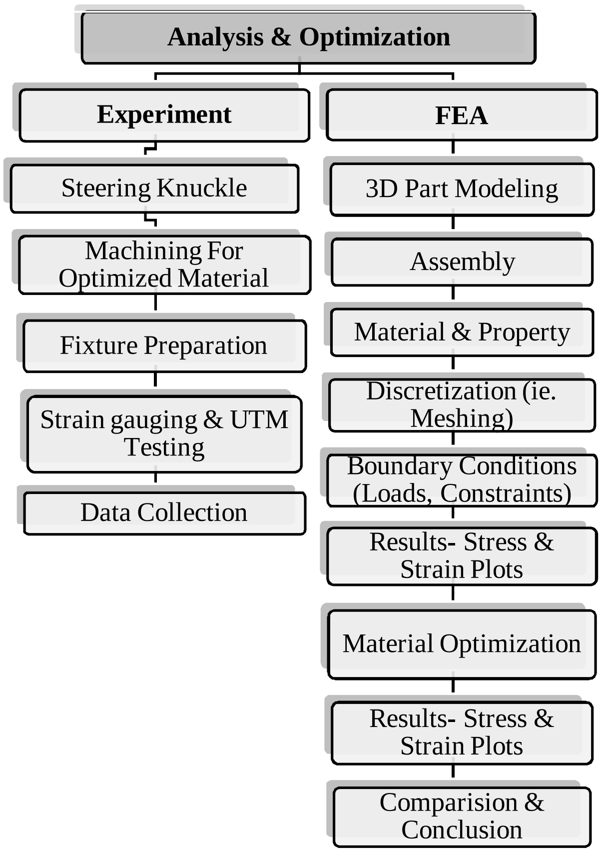
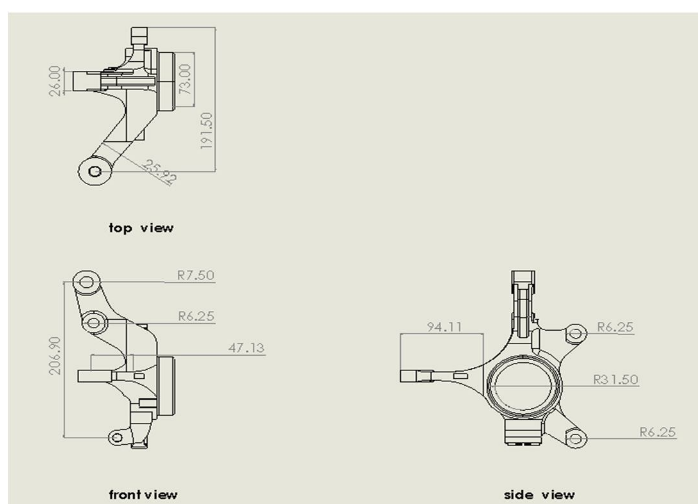
III. METHODOLOGY



IV. DESIGN OF STEERING KNUCKLE

A. 3D Model

Existing steering Knuckle cad model



Existing steering Knuckle drafting

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V. CALCULATIONS

The total weight of the selected vehicle is 1480 kg. For calculating breaking force acting on one wheel we have to distribute weight of vehicle for four wheels So that we get vehicle weight acting on one wheel. i. e. 1480/4 = 370 Kgs for one wheel

Breaking force = 1.5gm (g = 9.81m2 /s)
= 1.5*9.81 = 14.715 m/s2
= 14.715 *370 = 5444.55kgm2/s = 5444.55 N

Moment = breaking force * perpendicular distance
= 5444.55* 94 = 511787.7 N-mm

(For one wheel) This moment is acting on steering knuckle where brake calliper is mounted. Brake calliper is mounted at three locations therefore distributing moment at three points,

Moment = 511787.7/3 = 170596 N-mm

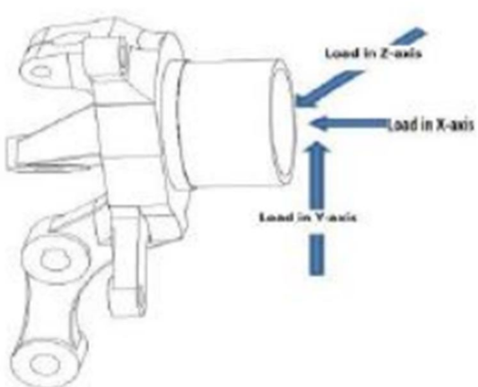
A. Force

For calculating force acting on steering knuckle, we required loading conditions as follows

LOADING CONDITIONS	
Braking Force	1.5gm
Lateral Force	1.5gm
Steering Force	**50N**
Load on knuckle hub in X direction.	3gm
Load on knuckle hub in Y direction.	3gm
Load on knuckle hub in Z direction.	1gm

Table 1 Loading Conditions

Since all load in X, Y, and Z direction are perpendicular to each other, the resultant of all the forces s given by,



$F=\sqrt{X^2 + Y^2 + Z^2}$

X = Y = 3g = 3*9.81*370 = 10889.1 N

Z = 1g = 1*9.81*370 = 3629.7 N

$F=\sqrt{10889.1^2 + 10889.1^2 + 3629.7^2}$

F=15821.5 N

VI. FINITE ELEMENT ANALYSIS

Finite element analysis (FEA) is a computational technique used for analyzing structures and systems by discretizing them into smaller elements. This method involves creating a digital model of the geometry, applying specific loads and boundary conditions, and dividing the model into a mesh of interconnected elements. The primary goal of FEA is to predict stresses and deflections within the geometry numerically. In this study, stress analysis was conducted using Ansys Simulation, a user-friendly FEA software package, to analyze five different designs. Details regarding material selection and boundary conditions are outlined briefly below.

FEA solution of engineering problems, to find deflections and stresses in a structure, require 3 steps:

1) Pre-processing
2) Solution
3) Post processing

A. *Geometry*

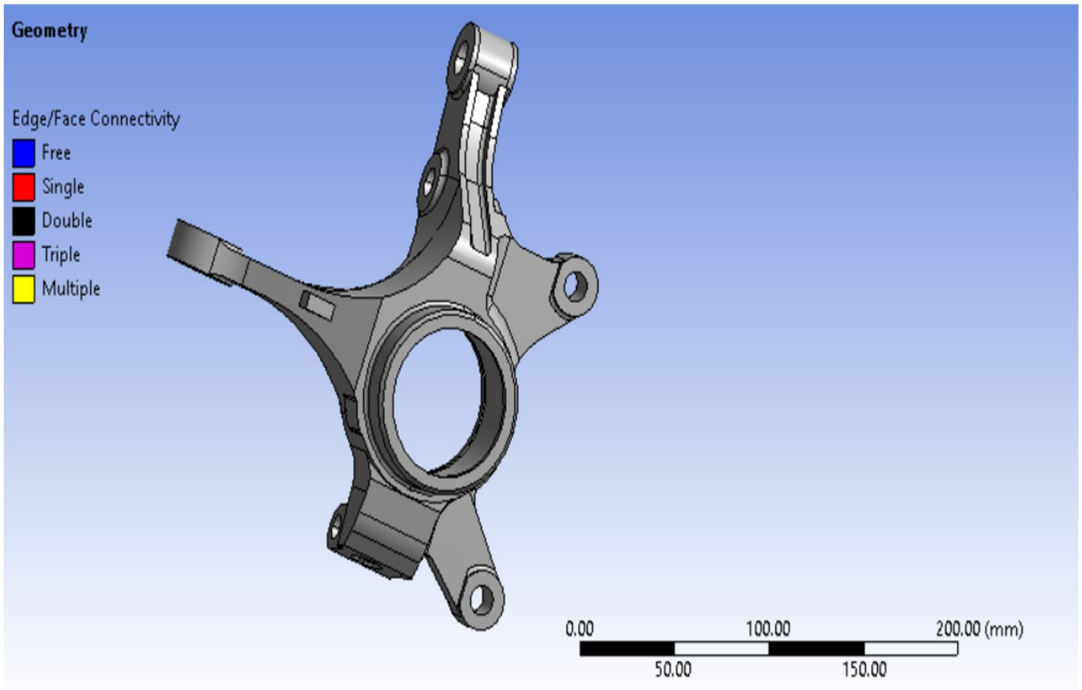


Fig. Geometry of the existing steering knuckle

B. *Meshing*

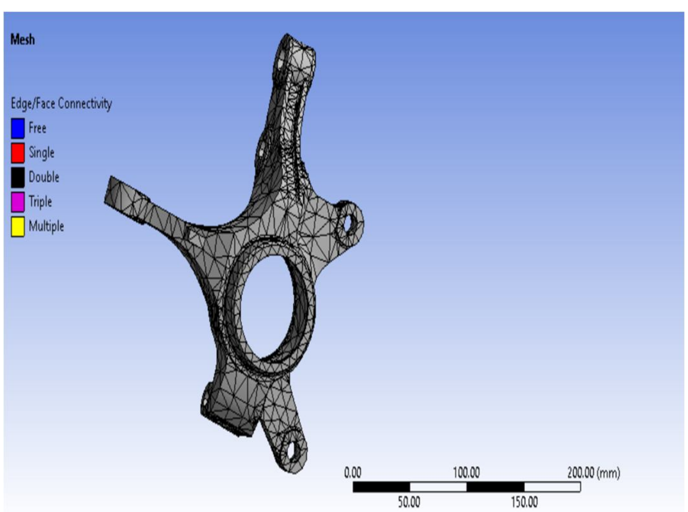
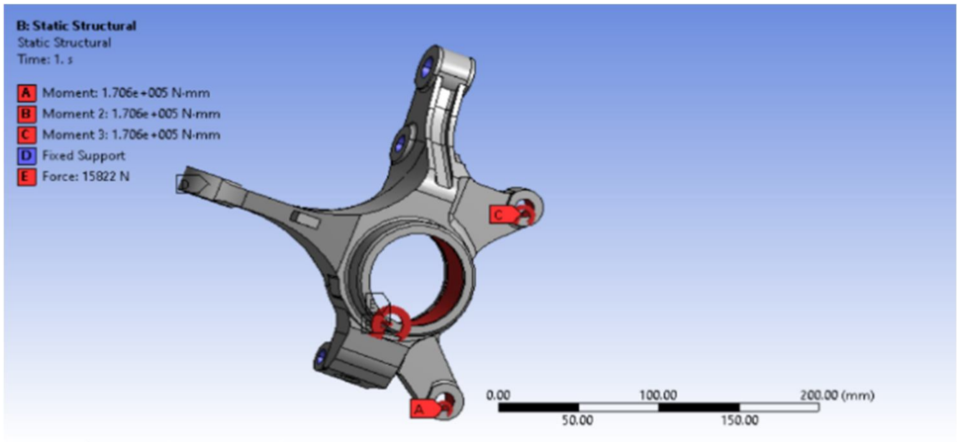


Fig meshing of the existing steering knuckle

NODES AND ELEMENTS:

Statistics	
Nodes	22391
Elements	12587

C. Boundary Condition



1) Cast Iron Material

Material properties

Properties of Outline Row 8: Gray Cast Iron

	A	B	C
1	Property	Value	Unit
2	Density	7200	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	1.1E-05	C^-1
5	Isotropic Elasticity		
6	Derive from	Young's Modulus and Poisson's...	
7	Young's Modulus	1.1E+11	Pa
8	Poisson's Ratio	0.28	
9	Bulk Modulus	8.3333E+10	Pa
10	Shear Modulus	4.2969E+10	Pa
11	Tensile Yield Strength	0	Pa
12	Compressive Yield Strength	0	Pa
13	Tensile Ultimate Strength	2.4E+08	Pa
14	Compressive Ultimate Strength	8.2E+08	Pa

WEIGHT

Properties	
Volume	3.561e+005 mm^3
Mass	2.5639 kg

Result

TOTAL DEFORMATION

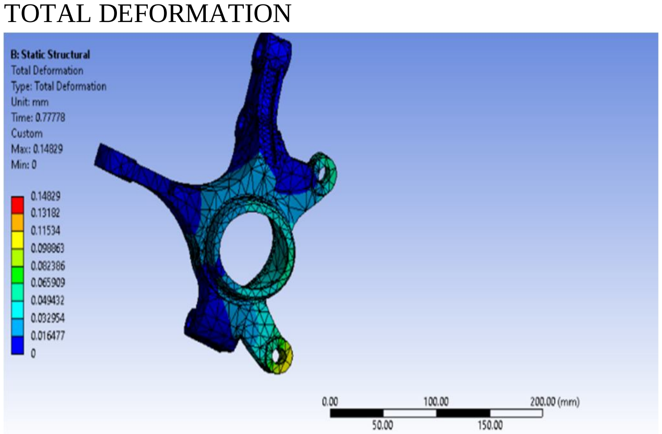


Fig. Total deformation of the existing steering knuckle

EQUIVALENT STRESS

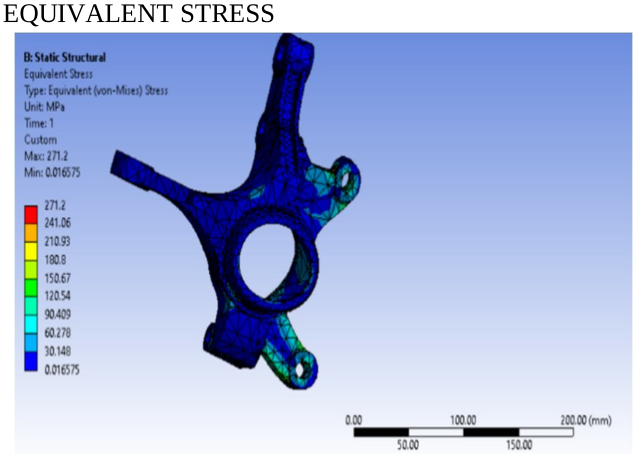


Fig. Equivalent stress of existing steering knuckle

Result

Parameter	EXISTING 4 WHEELER E.V. CHASSIS
weight	2.5639kg
Total Deformation (mm)	0.14829
Equivalent stress (Mpa)	271.2

2) *Aluminium Material*

Material properties

Details of "Aluminum Alloy"	
Common Material Properties	
Density	2.77e-06 kg/mm³
Young's Modulus	71000 MPa
Thermal Conductivity	table(T) = 0.14862 W/mm·°C
Specific Heat	8.75e+05 mJ/kg·°C
Tensile Yield Strength	280 MPa
Tensile Ultimate Strength	310 MPa

WEIGHT

Properties	
Volume	3.561e+005 mm³
Mass	0.9864 kg

Result

TOTAL DEFORMATION

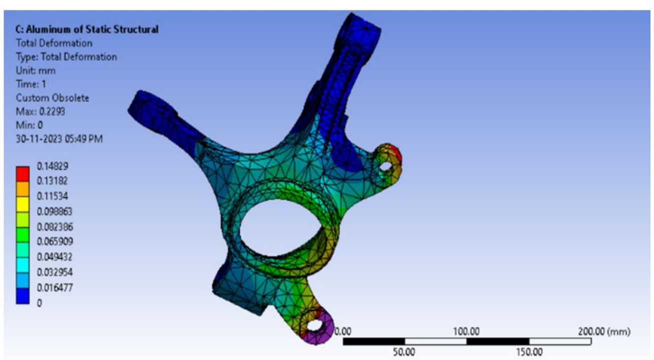


Fig. Total deformation of the existing steering knuckle

EQUIVALENT STRESS

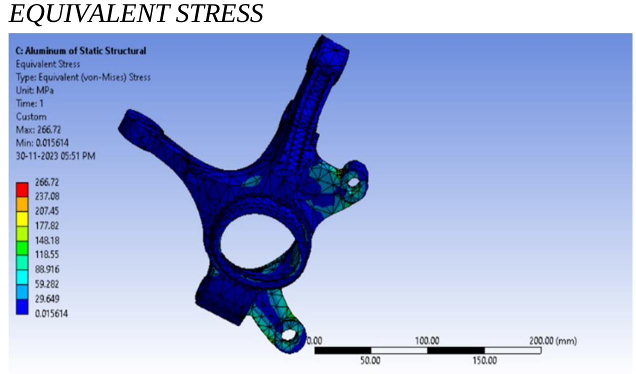


Fig. Equivalent stress of existing steering knuckle

After performing analysis on the existing steering knuckle the maximum equivalent stress was 266.72 MPa

Result

Parameter	*EXISTING 4 WHEELER CHASSIS*
weight	*0.9864 kg*
Total Deformation (mm)	*0.2293*
Equivalent stress (Mpa)	*266.72*

Comparison Between Materials

Parameter	CAST IRON	ALUMINIUM
Weight	2.5639kg	0.9864 kg
Total Deformation (mm)	0.14829	0.2293
Equivalent stress (Mpa)	271.2	266.72

VII. CONCLUSION AND FUTURE WORK

The primary objective of this study, aimed at reducing the mass of the existing knuckle to enhance fuel efficiency, underscores the critical importance of material selection and simple geometry. Aluminum 6061-T651 alloy, with a yield strength of 266.72 MPa, emerged as the optimal material due to its favorable physical and mechanical properties, coupled with its lightweight nature.

Furthermore, the optimization process effectively reduced the weight of the existing knuckle by 61.50%, while ensuring it still met strength requirements. This significant reduction in knuckle weight can contribute to an overall decrease in the car's weight, potentially enhancing fuel efficiency and overall performance. For future work, the application of application of CFRP layer to the Aluminum knuckle and further Physical tests are proposed to be conducted and scheduled to be reviewed.

VIII. ACKNOWLEDGEMENTS

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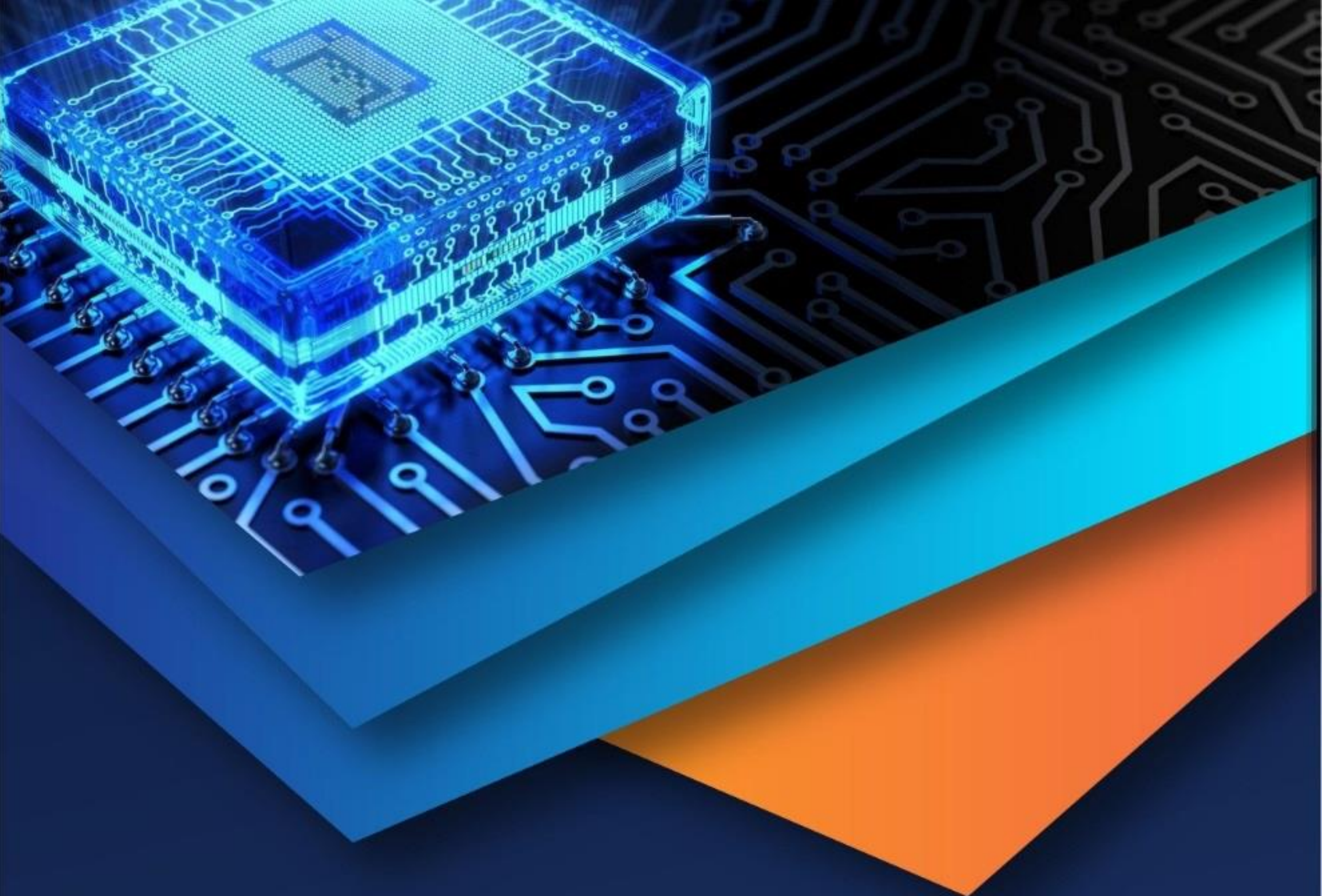

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