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Structural Analysis of Chassis Frame Using CFRP and ANSYS Software

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***Abstract:** Automotive chassis is an important part of an automobile. The chassis serves as a frame work for supporting the body and different parts of the automobile. The chassis frame has to withstand the stresses developed within a limit. Along with strength, an important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of the chassis. This work is aimed at work performed towards the static structural analysis of the automobile chassis in which study of the stresses developed and deformation of chassis frame of a truck has been done . The chassis is modelled in SolidWorks and finite element analysis has been done in ANSYS. a comparison of current conventional steel chassis structural Steel and Aluminum and CFRP chassis in terms of deflection and stresses must be made in order to select the best one. A discussion and analysis is also done which gives insight on various effects of unidirectional fiber orientations in the chassis on strength and stiffness.*
***Keyword:** ANSYS, SolidWorks, chassis, strength, stiffness, structural analysis.*

I. INTRODUCTION

The chassis generally represents the basic frame that determines the overall look of the vehicle. It is for fixing important parts of the vehicle. Chassis is a French term originally used to describe the frame parts and basic structure of a vehicle. The skeleton of the vehicle. A vehicle without a car body is called a chassis. Vehicle elements such as power plant, clutch gearbox, transmission system consisting of propeller shaft and rear axle, control system such as wheels and tires, suspension, brake and steering, and electrical system parts are also installed in the chassis frame. This is the default mount for all parts including the body. Therefore, it is also called a transport device. A car's chassis helps to keep the car rough, rigid and unbent. The car's chassis can reduce the overall vehicle noise, vibration and harm.

Engine, wheels, radiator, brakes, fuel tank, steering system, suspension system, transmission system (clutch, propeller shaft, differential, rear axle) these are the components of the chassis. It is the vehicle's superstructure. The entire vehicle is made up of the chassis and the body. The body and chassis of small and light cars are built as a separate unit, while in big vehicles, both are made as a single unit.

A. General Information

An automobile's chassis frame is a critical component. The automobile chassis frame is the vehicle's structural backbone. The primary purpose of the chassis frame is to support the body, various components of a car, and any payload that is placed on it. The chassis frame must be able to handle the pressures that are created as well as deformation, as well as shock, twist vibration, and other stressors.

The different types of automobile chassis frame are as follows:

1) Conventional Frame: The conventional frame is a load-bearing frame. The frame is responsible for transferring the vehicle's loads to the suspensions. This suspension is part of the vehicle's primary skeleton, which is supported on the axles by springs. The body is constructed of flexible materials such as wood, and the frame is separated by rubber mountings. The frame is constructed from channel or tubular box section.
2) *Ladder Chassis:* The ladder chassis is one of the earliest types of automobile chassis, and it is still utilised in the majority of SUVs today. Ladder chassis, as its name implies, is shaped like a ladder, with two longitudinal rails interconnected by lateral and cross bracing.

Two longitudinal rails interconnected by lateral and cross bracing.

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B. The Different types of Automobile Chassis

1) According to Control

a) Conventional Control Chassis: The engine is located directly in front of the driver's cabin. This layout does not make full use of the available space.

b) Semi-forward Control Chassis: Half of the engine is located within the driver's cabin, while the other half is located outside the driver's cabin.

c) Full-forward Control Chassis: The engine is entirely enclosed within the driver's compartment. Obviously, the most efficient use of space is accomplished in this configuration.

2) According to Fitting to Engine

a) Engine at front
b) Engine fitted at the back.
c) Engine fitted in front but crosswise
d) Engine fitted at the center of the chassis

3) Functions of Chassis

a) Endure shock loading.
b) To safety carry the maximum load.
c) Accommodate twisting on even road surface.
d) It must absorb engine & driveline torque.
e) Holding all components together while driving.

4) Types of Ladder Frame

Ladder frame are classified as follows.

a) I cross-section type of ladder chassis frame.
b) C cross section type of ladder chassis frame.
c) Rectangular Box (Intermediate) cross section type of ladder chassis frame.
d) Rectangular Box (Hollow) cross section type of ladder chassis frame.

5) Frame

a) The frame is the major component of the chassis on which the rest of the chassis is placed.
b) When the car is travelling on the road, the frame should be highly stiff and robust to endure shocks, twists, strains, and vibrations.

Frame are made of following sections:

- *Channel Section:* Channel Section used for long members.
- *Box Section:* Box Section used for Short members.
- *Tubular Section:* these section used for two wheelers, three Wheelers and matadors.

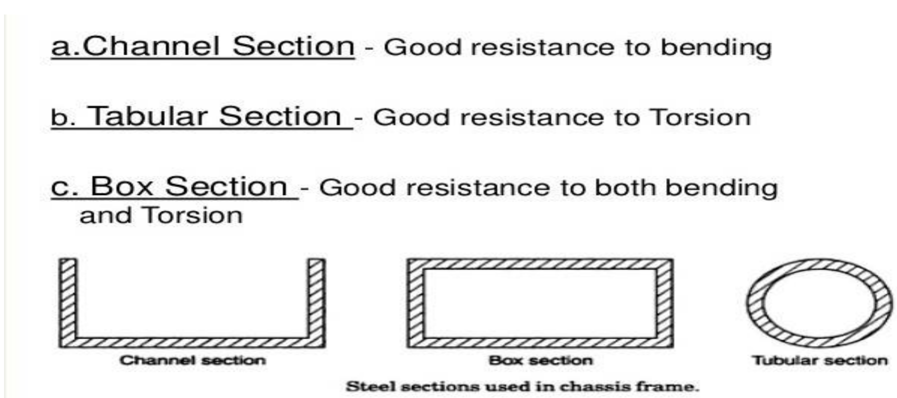

Figure 1. Types of Chassis Frames

6) *Types of Chassis frame*

a) *Conventional Frame*

- It's also referred to as a "non-load carrying frame." The loads on the cars are passed to the suspensions via the frame in this location.
- This frame is not designed to withstand torsion.

Figure 2. Conventional Chassis frame

b) *Integral Chassis frame*

- The load is also passed to the body structure in this sort of frame.
- This Frame, on the other hand, is rather hefty.
- A half frame is fixed in the front end of a semi integrated frame, on which the engine, gearbox, and front suspension are mounted.
- This frame is seen in various European and American automobiles.

Figure 3.Integral chassis frame

c) *Semi-integral Chassis Frame*

- There is no frame in this style of construction, and all assembly pieces are connected to the body.
- A significant number of mild steel pressings are used to build the chassis, floor, and body.
- Almost all automobiles and light commercial vehicles now have this type of structure.

Figure 1. Semi-integral Chassis frame model

II. LITERATURE REVIEW

Vijayan S N and Sendhikumar S (2015) recommended that relevant information from an existing EICHER heavy vehicle chassis be used for modelling and analysis of polymer composite materials, such as Carbon/Epoxy, and cross-sections such as C, I, and Box, subjected to the same load as a steel chassis. Analytical calculations based on stress distribution and deformation are used to validate the numerical results.

Cheeranjeeva Rao Seela and Vaikuntarao Matta (2015) discussed their work on the static structural analysis of truck chassis, in which they investigated the stresses and deformation of the chassis frame of EICHER 11.10 using three distinct materials: St52, Ni-Cr Steel, and CFRP in each case. PRO-E was used to model the chassis, while ANSYS was used to perform the finite element analysis.

According to Agarwal S Monika (2015), The purpose of the study is to generate results that will help to solve problems with commercial vehicle constructions such as strength, stiffness, and fatigue characteristics, as well as stress, bending moment, and vibrations. Static and dynamic analysis, combining current theoretical knowledge with new analytical methodologies, can help achieve this. The CATIA software is used to design a chassis. ANSYS will be used to do the finite element analysis.

This paper by Vijay Kumar Patel and R. I. Patel (2012) details the work done on the truck chassis' static structural analysis. Finite element techniques may be used to easily analyse structural systems such as the chassis. As a result, a suitable chassis finite element model must be constructed. PRO-E is used to simulate the chassis. The ANSYS Workbench is used to perform FEA on the modelled chassis.

The von Misses stress and shear stress for the chassis frame were computed by Rai Kumar, R et al (2014), and a finite element analysis was performed for validation on the Jeep chassis frame model. For the rectangular hollow box type, we used mild sheet steel, aluminium alloy, and titanium alloy to construct the chassis frame of the Jeep.

Patel H et al (2013) describe the work done to optimise the automobile chassis under the restrictions of maximum shear stress, equivalent stress, and chassis deflection. Finite element techniques may be used to easily analyse structural systems such as the chassis. For weight loss, a sensitivity analysis is performed. As a result, a suitable chassis finite element model must be constructed. PRO-E is used to simulate the chassis. The ANSYS Workbench is used to perform FEA on the modelled chassis.

A.Hazemohzammed, M.Yuvaraj, et al (2016) estimated the vonmises stress and shear stress for the chassis frame, and performed a finite element analysis to validate the model. For the rectangular hollow box type chassis structure, we used materials such as mild sheet steel, aluminium alloy, and titanium alloy. CATIA V5 was used for design, HYPERMESH was utilised for meshing, and ANSYS 16 was used for analysis in this project. B Jalindar.C,(2015) Traditional materials are replaced by a composite substance, Carbon Epoxy, in this thesis by Jalindar.C. The static load analysis of the TATA Super Ace was conducted using ANSYS workbench for validation, and solid mechanics was used to verify the results. The goal of this work was to gain a better understanding of the effect of varying the number of layers of reinforcement and fibre orientation on chassis strength. Deformations are acquired for several chassis orientations, and the optimum appropriate orientation for chassis design is determined.

Sandeep M.B.presented by the influence of fibre orientation on flexural strength for pure glass/epoxy composite material. The experimental findings revealed that bidirectional glass fibres with a 0-90° and a -45 +45" orientation have different flexural strengths.

Vijaykumar.V.Patel and R.I.Patel performed structural study on the ladder chassis frame using the ANSYS workbench, they demonstrated that the position of maximal Von Misses stress and maximum shear stress are at corner of side bar. The critical point Von-Mises stress magnitude is 190.38 MPa, whereas the maximum shear stress magnitude is 106.08 MPa. The greatest displacement is 3.0294 mm in magnitude.

III. METHODOLOGY

A. Key Assumptions in FEA for Design

Lists of typical project dependent assumptions are provided:

1) Geometry (CAD Model)
2) Properties (Metal, Non Metallic and Composite)
3) Mesh (number of Nodes and Elements)
4) Boundary conditions (Loads)
5) Linear Static
6) Transient response or time-dependent loading
7) Frequency response or sinusoidal loading
8) Random response

B. Loading Criteria

Chassis is too suitable for vehicles Tata ACE, Tata intra V30, Mahindra Bolero or Maxitruck + and Ashok Leyland dost +.
Material of chassis = structural steel, Aluminium and CFRP.
Length of chassis = 4400 mm
Width of chassis = 1550 mm
Wheel base: - 2450mm
Dimensions of side bar = 100mm x 70mm x 5 mm
Gross vehicle weight (G.V.W) = 2565 kg
Kerb weight = 1265 kg
The above-mentioned load (G.V.W) is applied as pressure. As a result, the total area of load application determined from chassis dimensions = 308000mm^2.
Total load to be applied = 2565x9.81=25162.65 N
Uniformly distributed load = total load/length of chassis. At each beam load to be applied on chassis Frame is Total weight/area of one side beam.
Each beam load is 12581.32N/ (4400*100) mm
Each beam load = 0.0285 N/mm^2 (Pressure).

Table 1: Methodology of Analysis of Chassis frame.

Objective No.	Statement of the Objective	Method/ Methodology	Status
1	Literature Review	Study of Chassis, Performance of Chassis, Composite Material and Ply sequence.	Journals, research papers and internet
2	Creating Geometric Model	Create the geometric model of chassis in Solid works	CATIA V5 / CAD modelling Software.
3	FEA analysis	Import the Model to ANSYS workbench and Assigning the material, Mesh Generation and Applying the Boundary conditions.	ANSYS workbench Analysis.
4	Comparing the results with different Selection of ply sequence.	The layer thickness is normally fixed, and fiber orientation angles are often limited to a discrete set such as 0°, ±30°, ±45°, ±75°, and 90°.	ANSYS ACP Pre-Post
5	Validation of Results	Comparing the Best results of different ply sequence.	ANSYS and Literature review.

C. Material properties

Continuous and discontinuous fibres placed in a matrix finish composite products. Because of the directional character of these ply fibres, the composite layer properties have a directional dependency. Anisotropic materials are those that have characteristics that are direction dependant. The stiffness and strength qualities of composite materials are highly dependent on the orientation of the fibres in the laminate.

D. Criteria used during Ply Orientation

Following criteria should be used during ply orientation:

1) On strength regulated laminates, paying attention to ply orientation can help prevent matrix and stiffness deterioration. Longitudinal loading is carried by the 0° ply orientation, transverse loading is carried by the 90° ply orientation, and shear loading is carried by the 45° ply orientation.
2) Place the 45° and -45° plies together to reduce in-plane shear; the in-plane shear is conveyed as tension and compression in the 45° plies.
3) Maintain symmetry around the laminate's centre line to reduce warpage and interlinear shear within the laminate.
4) The placement of certain ply orientations might impact the buckling strength and damage tolerance.
5) Stress orientation can be reduced by correct design or stepwise laminate thickness adjustments. Plies positioned at or near the neutral axis have less effect on laminate bending properties than plies placed at or near the outer ply orientations.

E. Geometric Model

The chassis model is created in Solid Works and then loaded into ANSYS Workbench 18.1 for load analysis. A comparison of existing conventional steel chassis structural Steel and Aluminum, and CFRP chassis follows the study. The structural backbone of a vehicle is the chassis frame. The chassis frame's principal function is to support the body, different automobile components, and any cargo that is placed on it. The chassis frame must be able to withstand the pressures generated, as well as deformation, shock, twist vibration, and other stresses.

Figure 5.Integral Chassis frame

F. Finite Element Analysis Workflow

There are three basic processes, namely: Pre- Processor, Solver and Post-processing. The problem's geometrical field, the type(s) of element to be used, the properties of the elements, materials, their geometrical properties (length, area, etc.), their element connectivity (mesh of the model), their physical restrictions (boundary conditions), and their charges are all defined in the pre-process (model definition). The algebraic equations, as well as the unknown values of the variable(s) in the primary field, are constructed in matrix form in the solution.

IV. RESULTS AND DISCUSSION

The chassis model is designed in Solid Works and then imported into ANSYS Workbench 18.1 for analysis under standard load conditions. The primary purpose of the chassis frame is to support the body, various components of a car, and any payload that is placed on it.

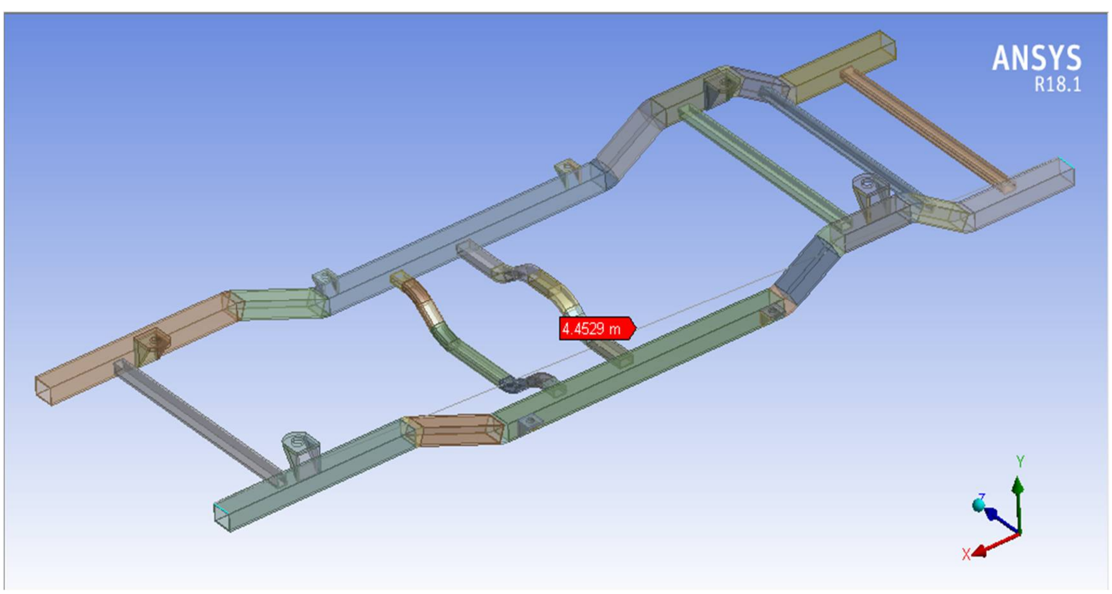

Figure 6.Geometric model of chassis

By Considering Structural analysis of Chassis frame made from Steel have total mass is 201kg with thickness of the material is 5mm.The maximum deformation of the Structural steel made Chassis is 1.20mm. The maximum deflection occurs at the Centre and less deflection at Chassis tip, it can be reduced by changing or use of carbon fibre reinforced polymers. Von-mises stress of the Steel made Chassis is 117.44mpa. Von-mises stress distribution less towards the leading and trailing edges and decreases towards the centre of Chassis.

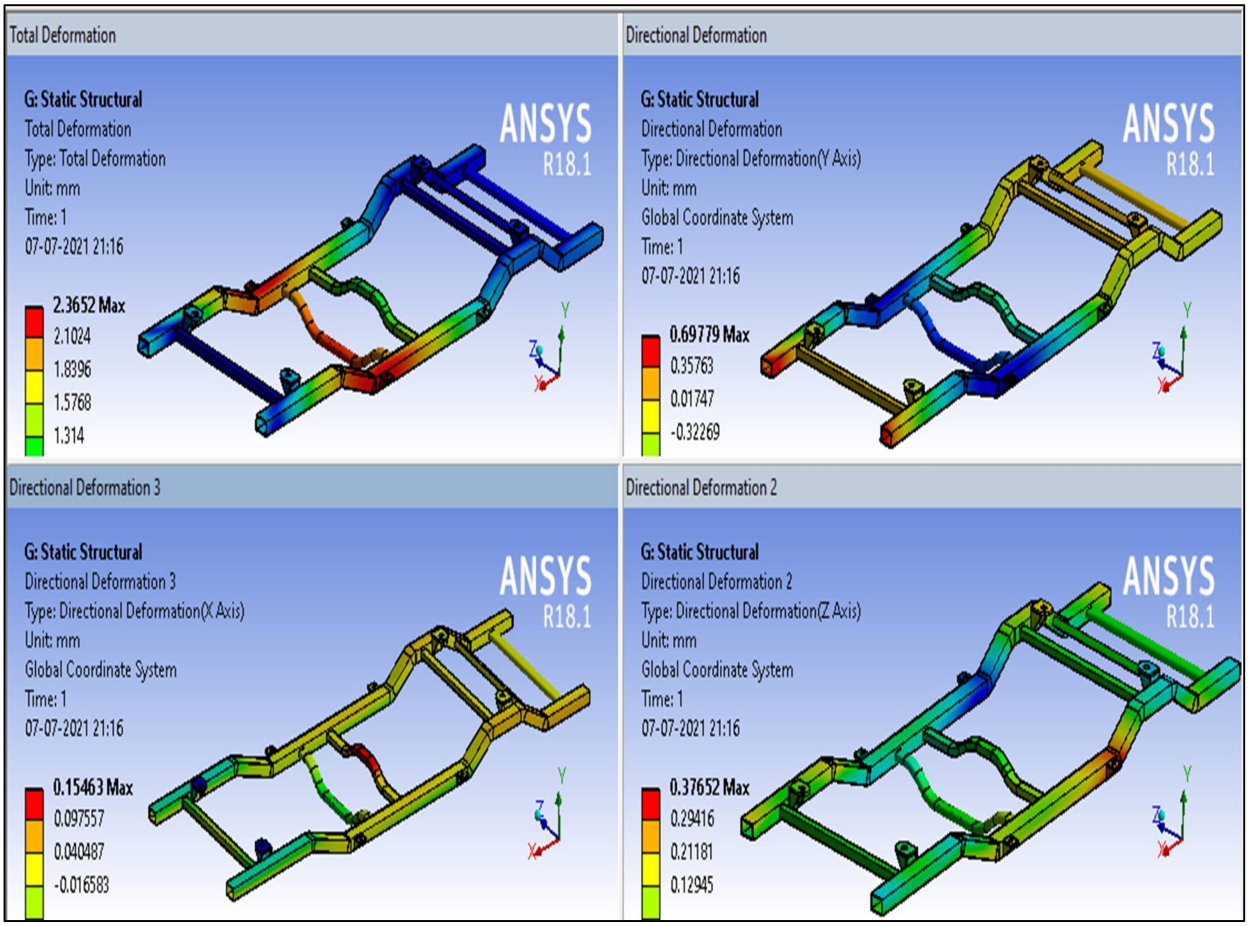

Figure 7.Total deformation of all axis

V. CONCLUSION

A. When compared to conventional metals, composites provide substantial weight savings. Composites can make structures that are 25-45 percent lighter than traditional steel constructions. Aluminium structural structures that satisfy the same functional criteria. This is owing to the composites' reduced density.

B. Composite densities range from 1260 to 1820 kg/in3 (0.045 to 0.065 lb/in3) depending on material form, compared to 7800 kg/in3 (0.10 lb/in3) for steel. Some applications may require larger composite sections to fulfil strength/stiffness requirements, although weight reductions will still be achieved.

C. Unidirectional fibre composites have roughly 4 to 6 times the specific tensile strength (ratio of material strength to density) of steel and aluminium.

D. Unidirectional composites have a 3 to 5times higher specific -modulus (the ratio of material stiffness to density) than steel and aluminium.

E. Fiber composites' high corrosion resistance helps to lower life-cycle costs.

F. Composites reduce the amount of complex pieces and expensive technical joints necessary to produce big metal structural components, resulting in cheaper production costs. To put it another way, composite parts can eliminate joints and fasteners, resulting in part simplification and integration.

Table 2. Comparison of Baseline model made up of Steel to CFRPs

SI No	Material	Density (Kg/m^3)	Weight in (N)	Total Deformation (m)	Strain	Stress (Pa)
01	Structural Steel	7850	1974.5568	0.0012	0.000858	17.74e7
02	Carbon Fibre Reinforced Polymers (CFRPs)	1504	696.7454	0.00236	0.002092	7.344e7

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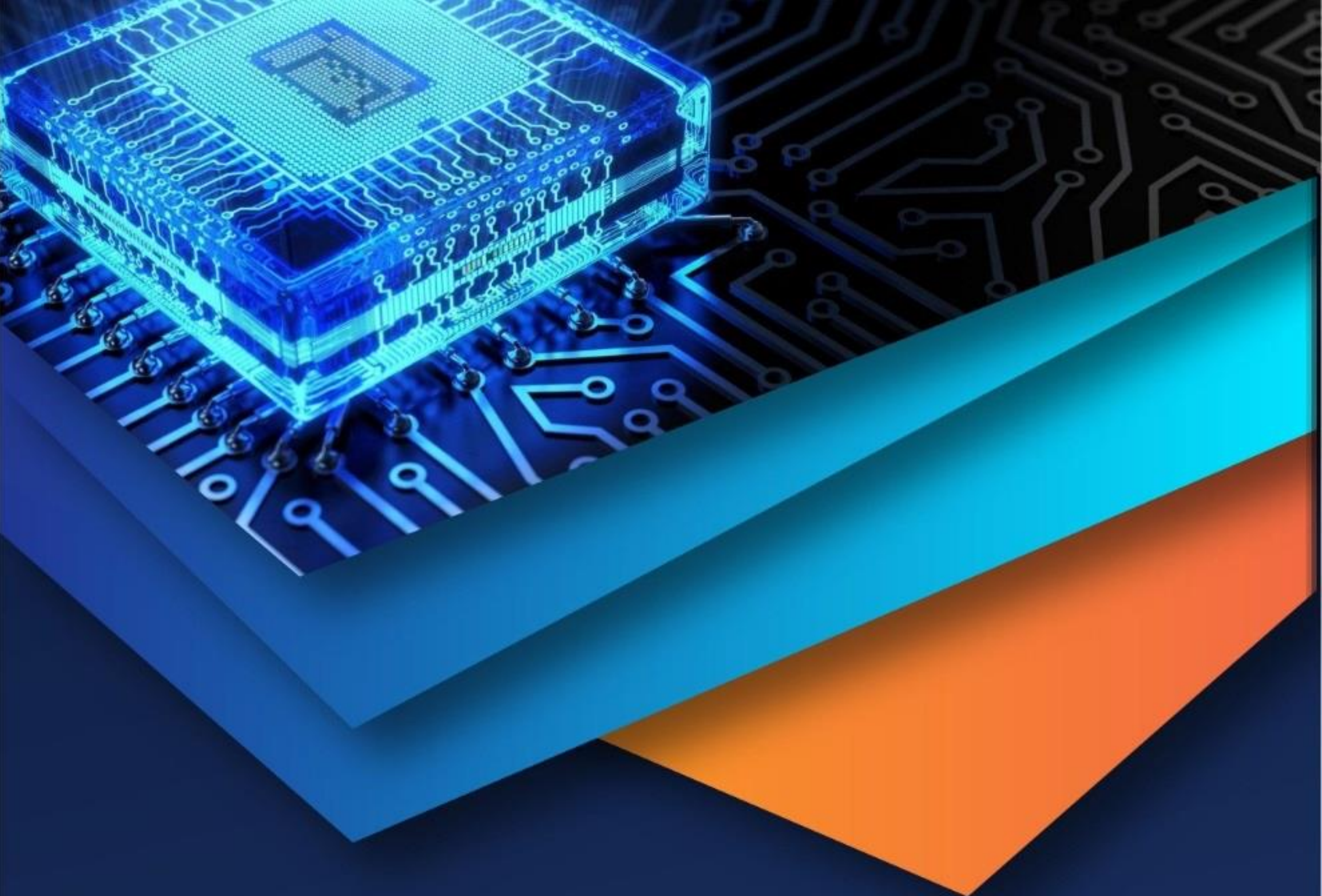

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