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Weight Optimization of Leaf Spring for Automotive Vehicle using Finite Element Modeling

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Abstract: The weight reduction has been the main focus of automobile manufacturers in the present scenario. The weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% 20%of the un spring weight. This achieves the vehicle more fuel efficiency and improved riding qualities. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system. In the present work, a steel leaf spring was replaced by a composite leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimension as that of steel leaf spring. In this study, leaf spring made of glass fibre reinforced polymer is designed and analyzed using ANSYS 16. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. It is found that composite leaf spring reduces the weight by 79.34% for EGlass/Epoxy. From the results of dynamic analysis of leaf spring, max deformation during deceleration is observed in Carbon- glass composite of leaf spring which is 75.39% more than max deformation in EN45 steel leaf spring.

Keywords: Carbon- glass composite, EN45 steel, E Glass/Epoxy, leaf spring, deformation, Spring deflection, suspension, Potential Energy.

I. INTRODUCTION

Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. A suspension system of vehicle is also areas where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity. To improve the suspension system, many modifications have taken place over the time. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the un sprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. Inventions of parabolic leaf spring, use of composite materials for these springs are some of these latest modifications in suspension systems. This seminar mainly focuses on the implementation of composite materials by replacing steel unconventional leaf springs of suspension system. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the un spring weight.

II. METHODS

Leaf springs are made out of flat plates. The advantage of leaf spring over helical spring it that the ends of the spring may be guided along a definite path as it deflects to act as structural member in addition to energy absorbing device. Thus the leaf springs may carry lateral loads, brake torque,

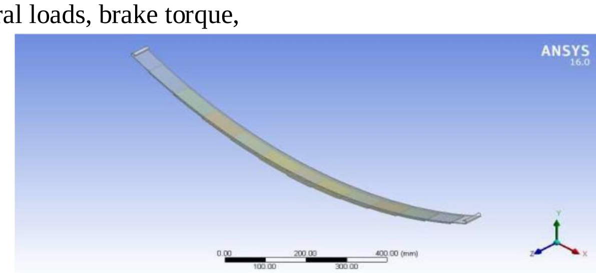

Fig No-1 Laminated Leaf Spring

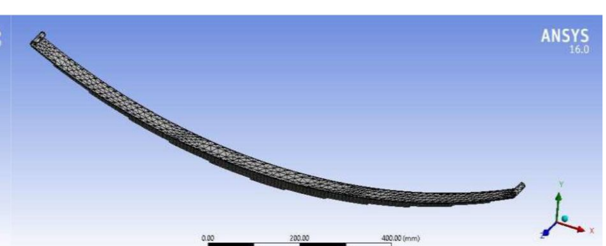

Fig No-2 Meshing of leaf Spring

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Driving torque etc., in addition to shocks. The general procedure in ANSYS design modeler is explained in step by step

1) *Step1:* Choose plane –YZ and draw sketch which represents the top layer of the spring
2) *Step2:* Extrude in normal direction with depth = 40 mm. you will get 3-Dimensional layer of leaf
3) Spring
4) *Step 3:* Draw sketches from the bottom of first layer simultaneously repeat the same procedure for all other 9- layers and extrude with the same width.
5) *Step 4:* Draw all other parts sketches and use 3D operation methods like extrude, revolve, pattern etc. to get complete assembly.

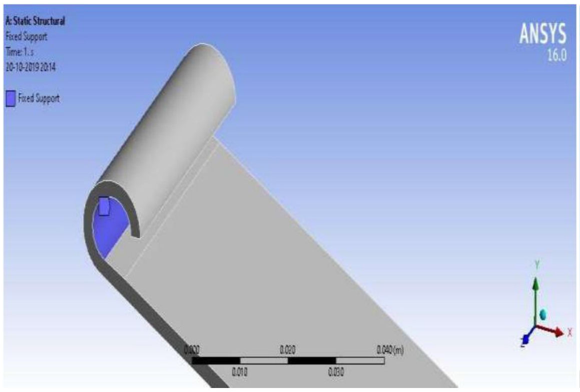

Fig No-3 Fixed Support of Leaf Spring

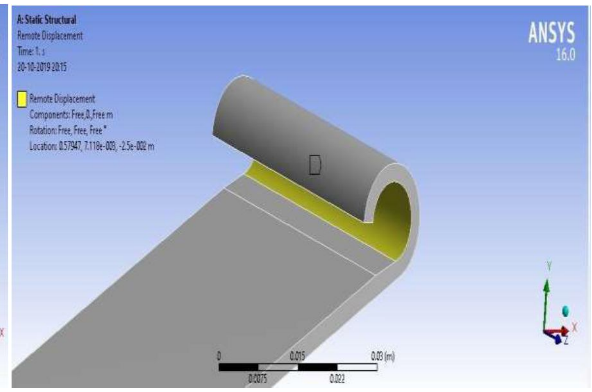

Fig No-4 Remote Displacement

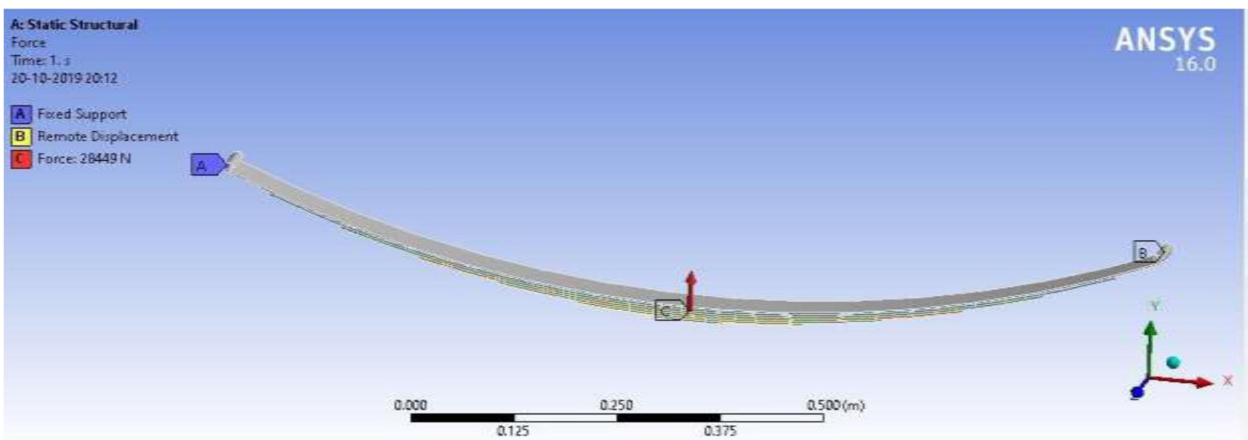

Fig No-5 load Applied in Leaf Spring

Finite element based software ANSYS 15.0 was used step by step for static analysis of steel leaf.

Table No-1 Dimensions of Leaf Spring

Parameter	Value	Parameter	Value
Length of Master Leaf (2L)	1151mm	Thickness (t)	6 mm
Effective length (L)	526 mm	Deflection of Leaf Spring	117 mm
Radius of Master Leaf (R)	1398 mm	Camber Length	58.5 mm
Number of Full Leaves	2	Eye Diameter	9 mm
Number of Graduated Leaves	8	Center Bolt Diameter	10 mm
Leaf Width (b)	50 mm	Thickness (t)	6 mm

III. MATERIALS

Table No-2 Mechanical Properties of Steel EN45

Material	Steel EN45	Unit
Density	7850	Kg/m^3
Poisson's Ratio	0.266	
Young's Modulus	$2.1x10^5$	N/mm^2
Yield Tensile Strength	1158	MPa
Ultimate Tensile Strength	1272	MPa

Table No-3 Mechanical Properties of Carbon/Glass Epoxy Composite

Material	Carbon/Glass Epoxy Composite	Unit
Density	1672	Kg/m^3
Poisson's Ratio	0.275	
Young's Modulus	$1.34x10^5$	N/mm^2
Yield Tensile Strength	280	MPa
Ultimate Tensile Strength	300	MPa

IV. RESULT AND DISCUSSIONS

Table No- 4 Results during Acceleration

Parameter	Steel EN45	Carbon- glass composite	Epoxy e-glass	Copper Alloy
Max Stress (Pa)	$1.5710 X 10^9$	$5.0467 X 10^9$	$1.7519 X 10^9$	$1.7168 X 10^9$
Max Deformation (m)	0.5819	0.75585	4.004	1.025

Table No-5 Results during Deceleration

Parameter	Steel EN45	Carbon- glass composite	Epoxy e-glass	Copper Alloy
Max Stress (Pa)	$5.345 X 10^9$	$7572 X 10^9$	$5450 X 10^9$	$5331 X 10^9$.
Max Deformation (m)	0.279	1.134	1.245	0.354

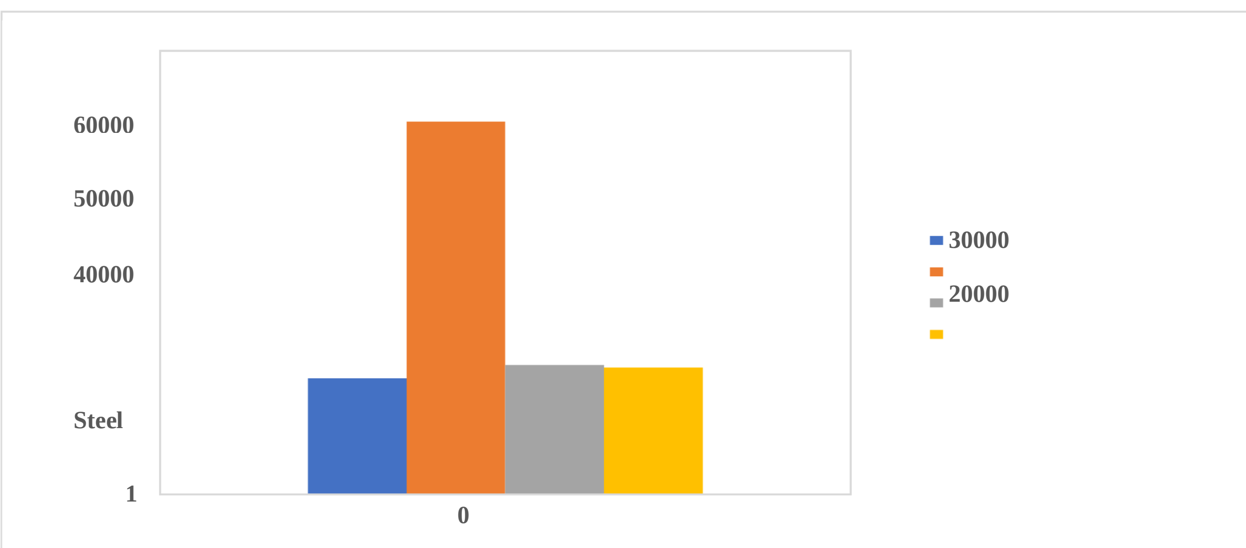

Fig No.- 6 Max. Stress Results during Aceleration

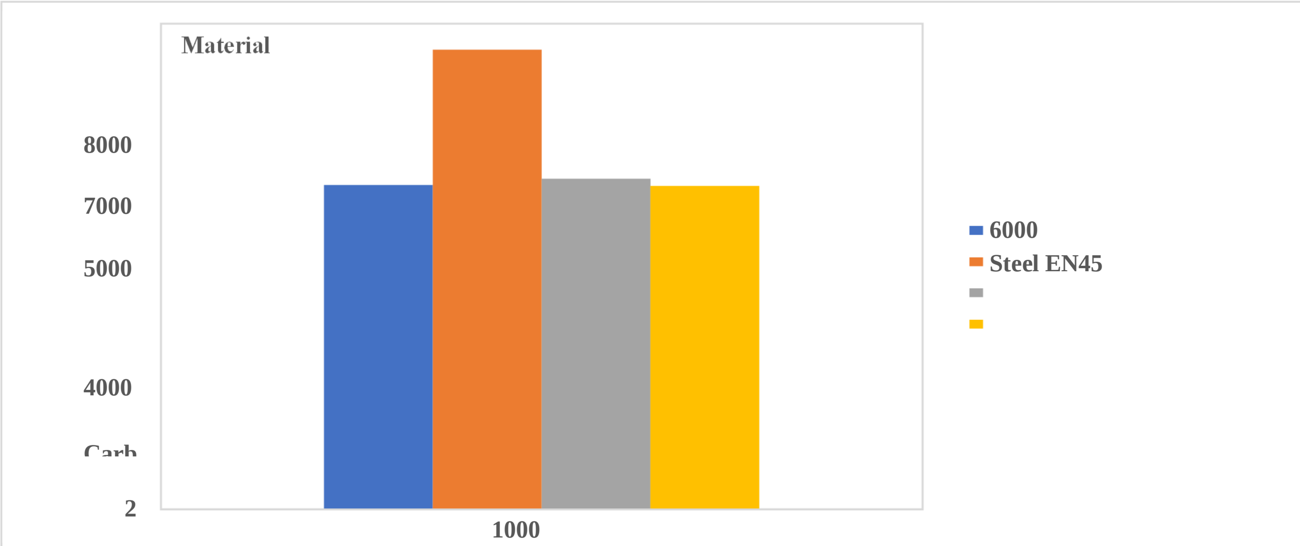

Fig No.-7 Max. Stress Results during Deceleration

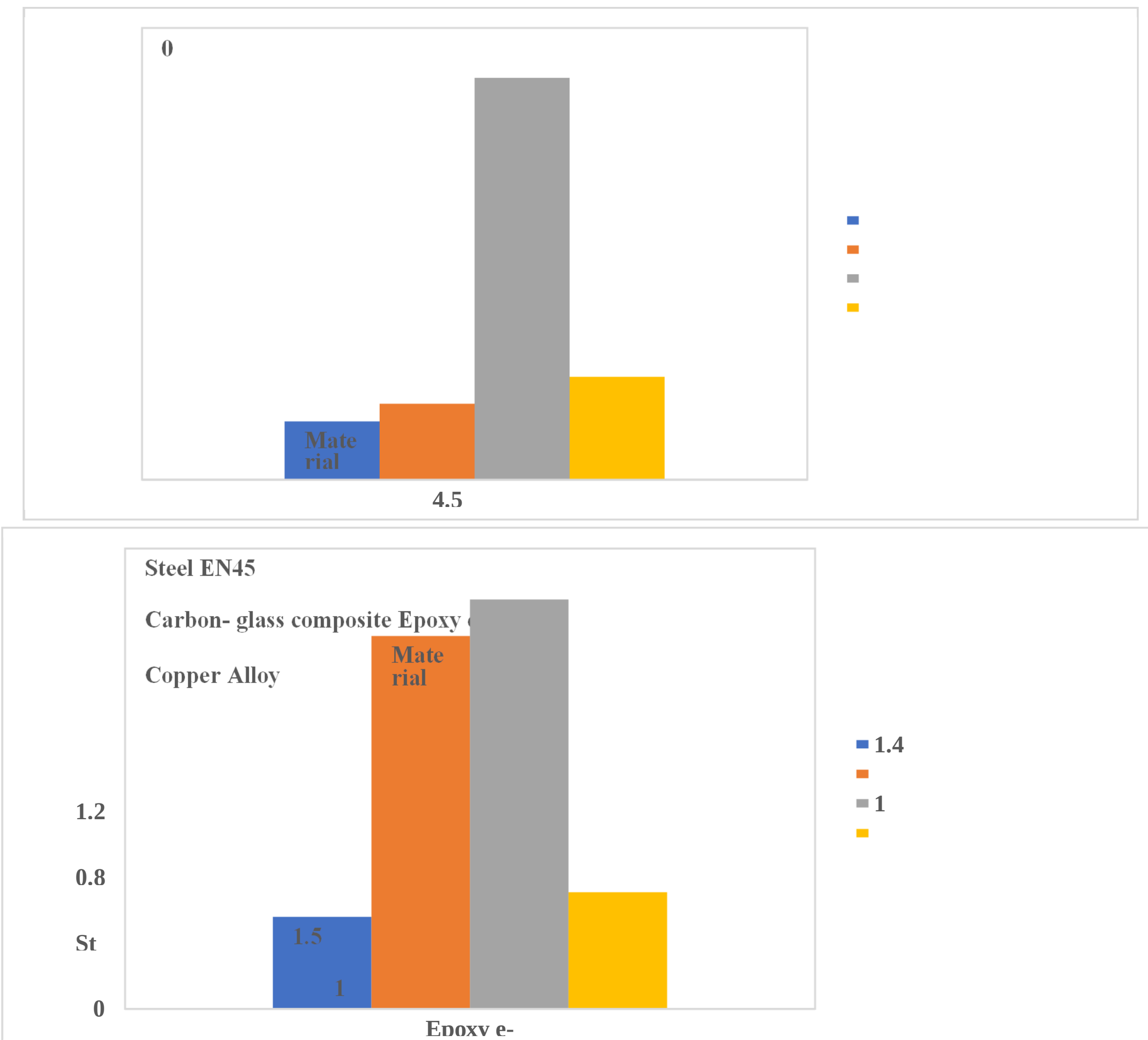

Fig No.-8 Max. Deformation Results during Acceleration and Deceleration

V. CONCLUSION

A. Composite leaf spring reduces the weight by 79.34% for EGlass/Epoxy. Since Displacement is very high for Carbon/Glass Epoxy Leaf Spring, it may cause slight Discomfort.

B. From the results of dynamic analysis of leaf spring, max deformation during decelerations observed in Carbon- glass composite of leaf spring which is 75.39% more than max deformation in EN45 steel leaf spring and max stress results during deceleration is observed in Carbon- glass composite of leaf spring which is 41.66% more than max stress in EN45 steel leaf spring.

C. From the results of dynamic analysis of leaf spring, max deformation during acceleration is observed in Carbon- glass composite of leaf spring which is 29.89% more than max deformation in EN45 steel leaf spring and max stress results during acceleration is observed in Carbon- glass composite of leaf spring which is 22.11% more than max stress in EN45steel leaf spring.

D. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring both from stiffness and stress point of view.

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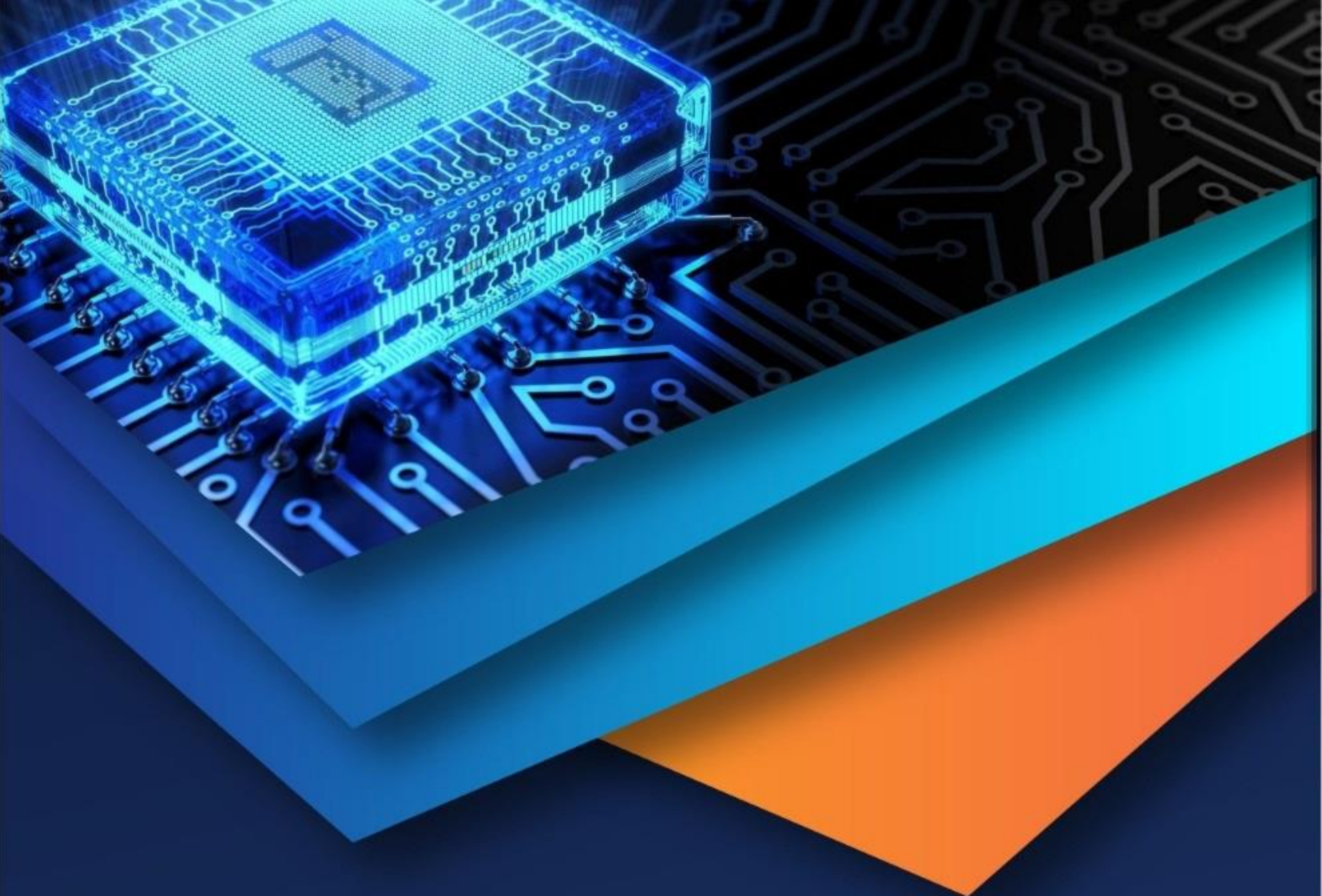

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