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Topology Optimization of Three-Wheeler Electric Vehicle Brake Pedal

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Abstract: In this project a new design is proposed on the 3 wheeler vehicle brake pedal for weight reduction and it is analyzed by software named FEA. In this an electrical three-wheel vehicle brake pedal is designed for weight optimization. Brake pedals are widely used in all automotive, which acts as a linkage between occupant and brake mechanism. Existing design seems to be overdesigned as per requirement, FEA used to apply cantilever load Optistruct solver used to perform topology optimization. The model of an existing brake pedal was generated using SolidWorksV5 modeling. Furthermore, the FEA analysis is done using ANSYS workbench 21. A three-wheel vehicle brake pedal was analyzed and optimized for weight reduction in this study. Optimize design will be tested using compression loading UTM machine.
Keywords: ANSYS, Universal testing machine (UTM), Finite Element Analysis (FEA), Electrical vehicle, Optistruct solver

I. INTRODUCTION

The automotive industry is constantly striving to produce lightweight vehicles to enhance energy efficiency and reduce emissions. vehicle weight plays a crucial role in determining the performance and efficiency of a car, as reducing the mass of a vehicle results in lower energy consumption. studies have shown that for every 10% reduction in vehicle weight, energy consumption can be reduced by 5-7% (cite). The brake system in a typical automobile operates by transmitting the force applied by the driver on the brake pedal, through hydraulic brake fluid, to the brakes at each wheel. The brake pedal serves as the interface between the driver's foot and the master cylinder of the brake system, allowing the driver to control the speed of the vehicle and bring it to a stop.

In recent years, there has been a growing focus on lightweight materials and their applications in automotive components. Brake pedals, traditionally made from steel, are now being considered for alternative materials to reduce weight while maintaining or improving performance. This study focuses on the optimization of the brake pedal design for weight reduction using topology optimization. The brake pedal of the Mahindra Treo is chosen as the subject for this study. The CAD model of the brake pedal is developed using SolidWorks, a 3D modeling software. The objective of the optimization design is to minimize the weight of the brake pedal while ensuring its structural integrity and performance requirements are met. This research aims to explore the use of alternative materials and design approaches for brake pedal construction, with a focus on reducing weight and cost without compromising safety or performance. The study utilizes topology optimization to achieve these objectives, aiming to contribute to the ongoing efforts in the automotive industry towards lightweight design and improved energy efficiency.

II. PROBLEM STATEMENT

Presently, automotive sedulity continues to strive for lightweight vehicles for perfecting energy effectiveness and emigration reduction. It's vital to design vehicles with an optimum weight for a better performance of the 3-wheeler. In this field, which has boundaries with fixed morals and regulations, manufacturers continue to work on characteristics, structures, and types of material to develop new factors, which have the same safety specifications but are cheaper than current products the main model. The initial weight of the model is calculated as 437 g. When the data obtained as a result of topology optimization are examined, the maximum displacement is 0.94 mm and the maximum stress value is 103.9 MPa

III.METHODOLOGY AND OBJECTIVE

A. Objective

1) To study 3-wheeler brake pedal component factors affecting its functionality.
2) To develop a 3D CAD model using SOLIDWORKSV5 and perform FEA analysis using ANSYS Workbench on a 3-wheeler brake pedal using static loading.
3) To study Topology optimization of 3-wheeler brake pedal.
4) To perform Topology optimization analysis of the brake pedal by using FEA.

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5) Experimental stress analysis of 3-wheeler brake pedal using load applied through UTM
6) Comparative analysis between FEA & Experimental results.

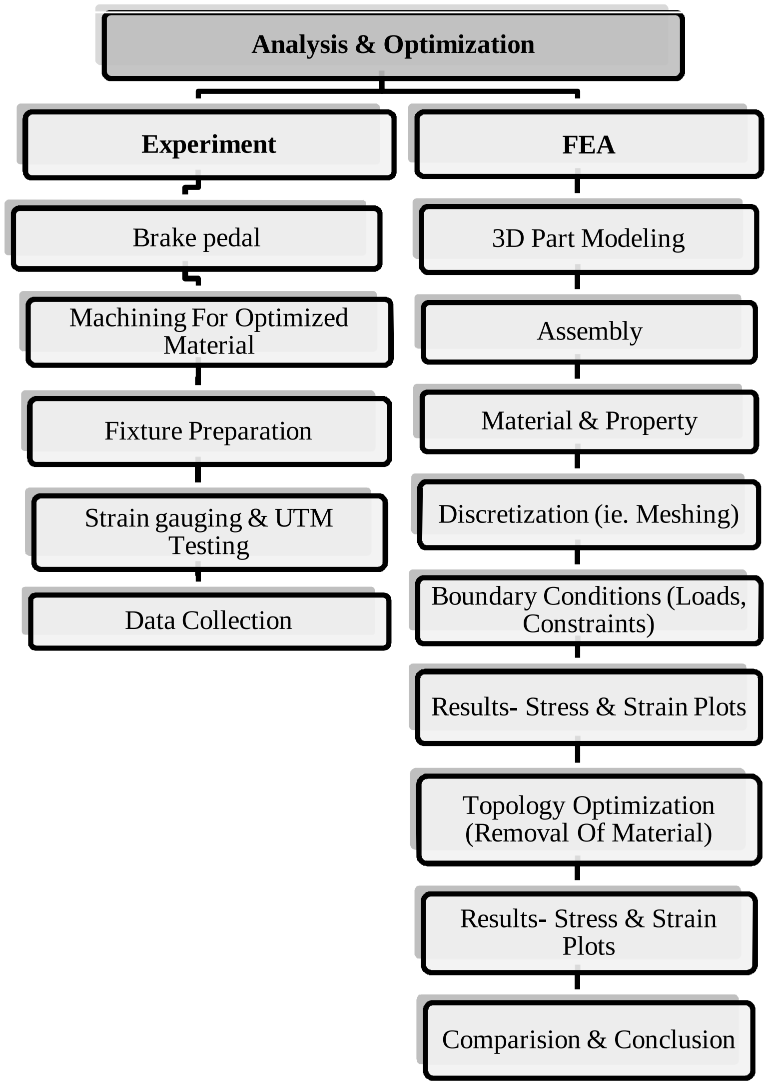


Fig 2 Flowchart of the methodology of the project

IV. DESIGN OF BRAKE PEDAL

A. 3D Model

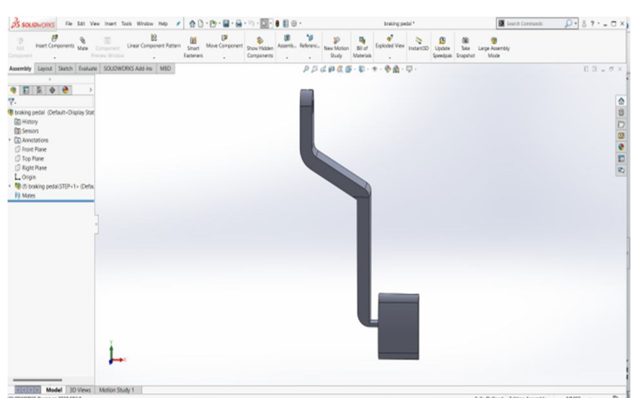


Fig. 3 Three-wheeler electric vehicle brake pedal

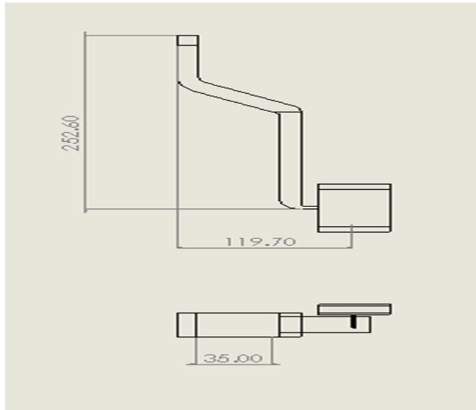


Fig. 4 Drafting Three-wheeler electric vehicle brake pedal

V. FINITE ELEMENT ANALYSIS

A. Geometry

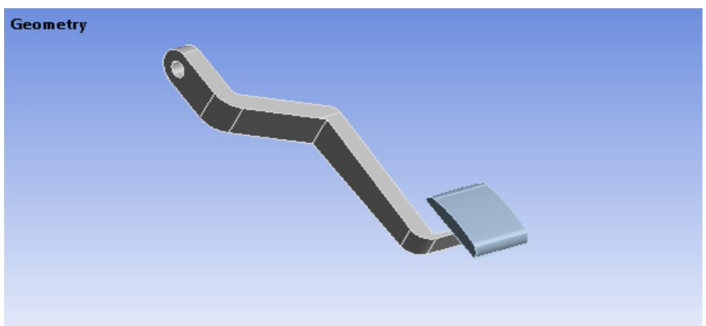


Fig 5. Geometry of Three-wheeler electric vehicle brake pedal

Properties	
Volume	1.814e+005 mm³
Mass	1.424 kg

B. Material properties

Details of "Structural Steel"	
Common Material Properties	
Density	7.85e-06 kg/mm³
Young's Modulus	2e+05 MPa
Thermal Conductivity	0.0605 W/mm·°C
Specific Heat	4.34e+05 mJ/kg·°C
Tensile Yield Strength	250 MPa
Tensile Ultimate Strength	460 MPa

C. Meshing

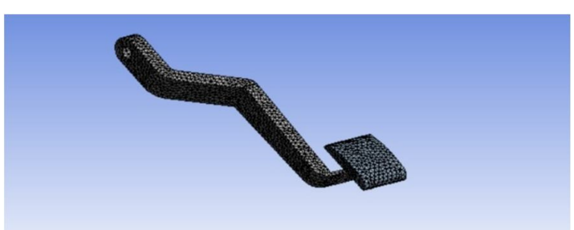


Fig 6 Finite element mesh model of Three-wheeler electric vehicle brake pedal

D. Nodes and Elements

Statistics	
Nodes	22223
Elements	13571

Type	Element Size
Element Size	5.0 mm

E. Boundary Condition

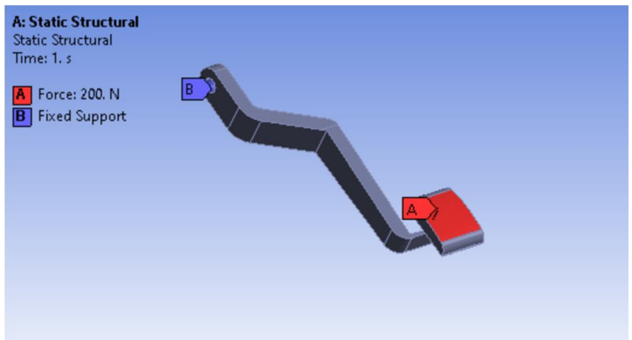


Fig 7. Boundary condition of Three-wheeler electric vehicle brake pedal

F. Results

1) Total Deformation

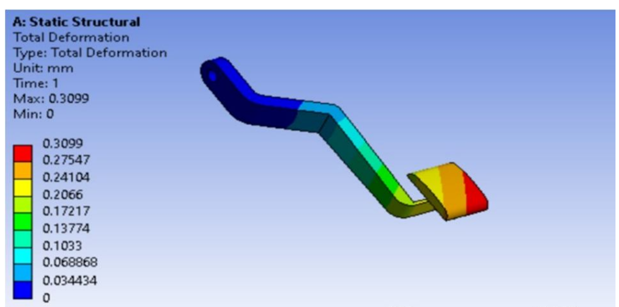


Fig 8 Total deformation of Three-wheeler electric vehicle brake pedal

The Max. And Min. Total Deformation is 0.3099 mm and 0 mm respectively.

2) Equivalent Stress

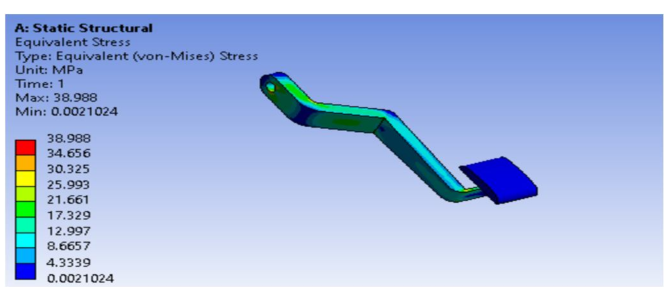


Fig 9 Equivalent Stress of Three-wheeler electric vehicle brake pedal

The Max. and Min. Stress Distribution in Al 6061 is 11.285 MPa and 0.014374 MPa respectively.

3) Equivalent Strain

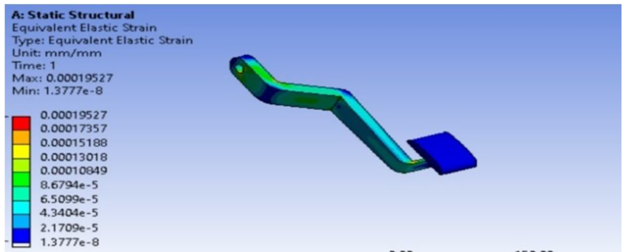
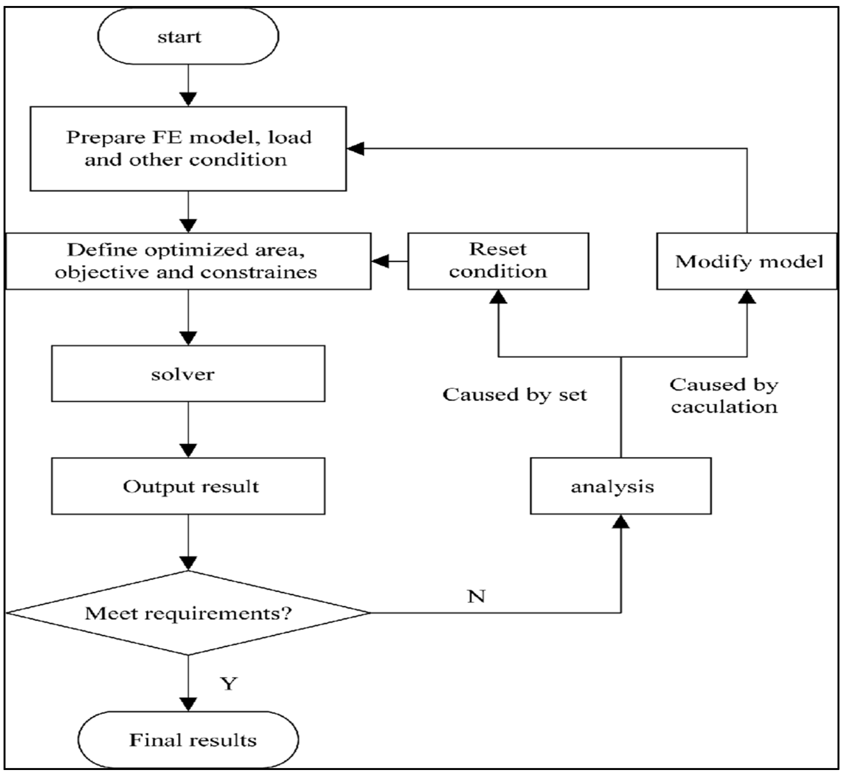


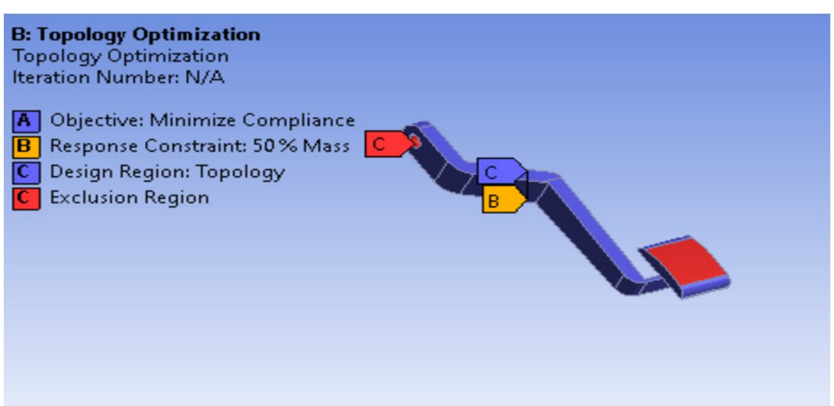
Fig 10 Equivalent Strain of Three-wheeler electric vehicle brake pedal

The Max. and Min. Strain Distribution is 0.00019527 and 1.3777e-8 respectively.

G. Topology Optimization

1) Analysis





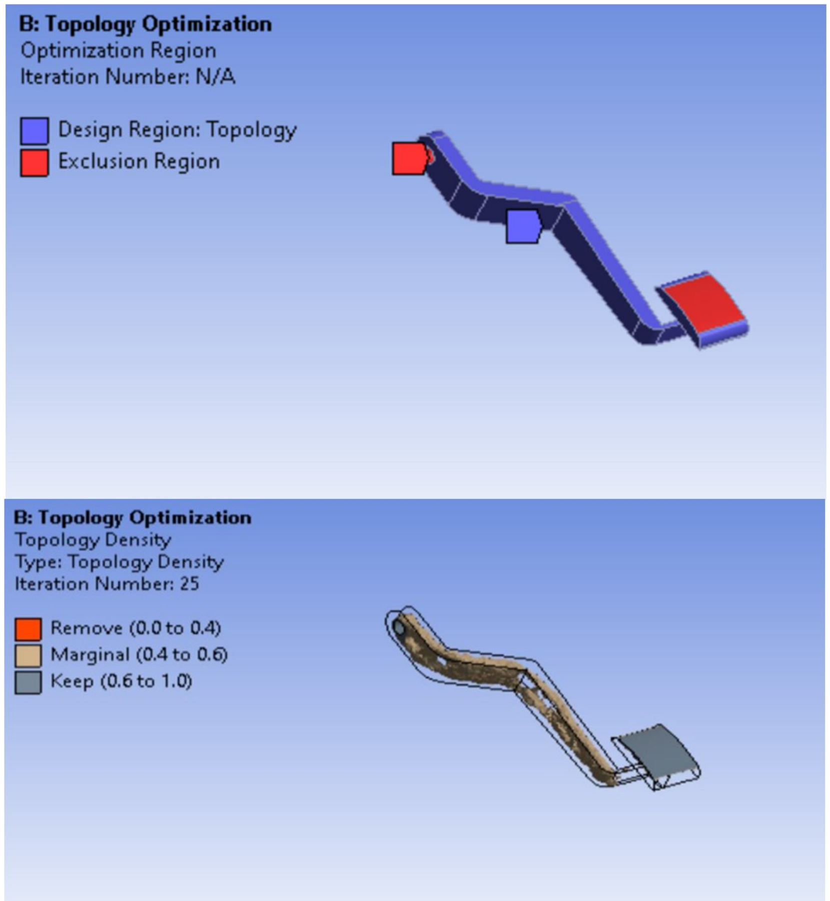


Fig 11 Results of Topology Optimization

- The thing of the mathematically described optimization issue is to reduce the compliance of the structure under a given set of constraints, similar to volume or stress limitations.
- Compliance is a dimension of the distortion or strain energy caused by loads or forces outside the structure.
- Also the response constraint is added like how important mass we need to retain. The confluence delicacy of the analysis was set to 0.1.
- The quantum of mass to be retained was set to 50. After feeding all the parameters we performed the topology optimization.
- The result was gathered after 25 duplications.

Parameter	STANDARDBRAKE PEDAL
weight	1.424 kg
Total Deformation (mm)	0.3099
Equivalent stress (Mpa)	38.988
Equivalent strain	0.00019527

VI. CONCLUSION

1) The design and static structural analysis of the existing 3-wheeler electric vehicle brake pedal has been carried out.
2) The stress and displacements have been calculated using ANSYS 21 for 3 3-wheeler electric vehicle brake pedals.
3) From the static analysis results it is found that there is a maximum displacement of 0.3099 mm and Equivalent stress of 38.988 Mpa in the existing 3-wheeler electric vehicle brake pedal
4) By analyzing the design, it was found that all the stresses in the existing 3-wheeler electric vehicle brake pedal were well within the allowable limits and with a good factor of safety.

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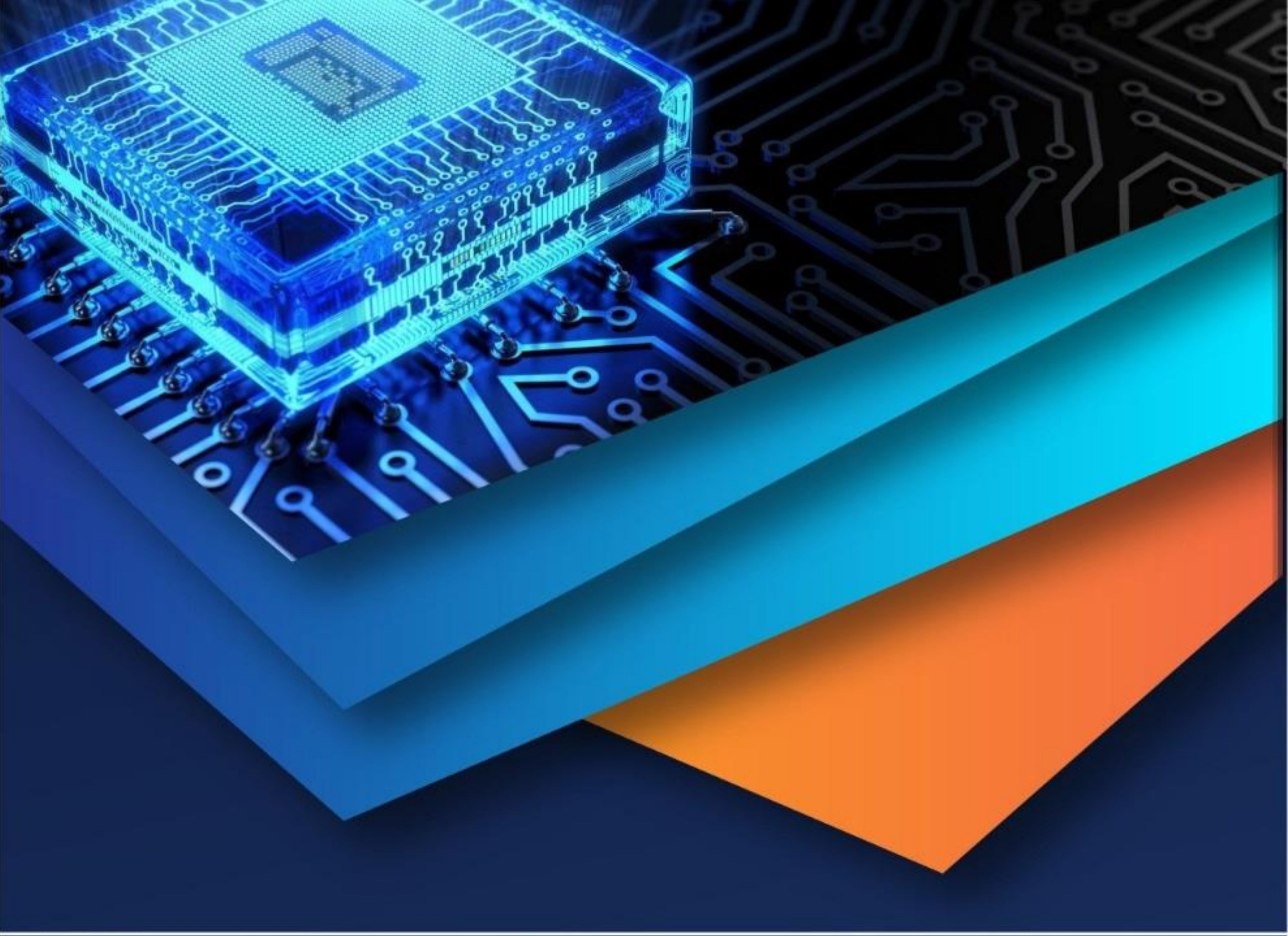

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